Universidade de Aveiro Departamento de Economia, Gestão e Engenharia Industrial
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Reza Sirous

Identifying and Overcoming Barriers in Launching Sustainable Energy Projects in the Industrial Sector Using Multi-Methodology

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Engenharia e Gestão Industrial, realizada sob a orientação científica do Doutor Rui Jorge Ferreira Soares Borges Lopes, Professor Auxiliar do Departamento de Economia, Gestão e Engenharia Industrial da Universidade de Aveiro.

"In the Name of God, the Merciful, the Compassionate"

“The significant problems we face today cannot be solved at the same level of thinking at which they were created.” Albert Einstein.

o júri

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Preface and Acknowledgement

Since my early days of education in the University of Aveiro, in Portugal as a curious Iranian student I became interested in Energy Management subjects and after passing a curriculum course with that theme, I decided to do my dissertation in energy optimization. I started my work by directions of my Energy Management Professor, Dr. Nelson Martins from Mechanical Engineering Department. I decided to use decision making techniques in optimization of energy consumption. With this purpose in mind I chose Professor Dr. Rui Borges, as my supervisor who advised me to explore different methodologies among which was Soft System Methodology (SSM) that concludes the basic theme of this work. My first site visiting in Iran which was from an automobile parts manufacturing industry set near the capital of Iran brought me to the conclusion of a compound model development. My attention to optimize energy management system in that factory was not enough and I understood, according to what I later studied in SSM literature, that any change in an organization should be accompanied by the studies of the system culture. Later conversations and interviews with Professor Ahad Azami active energy sustainability consultant in Iran, and Eng. Saleh Akbarzade director in petrochemical industry in Mahabad city of West Azerbaijan province helped me in model development by SSM. My special thanks to my Professors of University Aveiro who were always ready to help students in their idea developments persistently, and my beloved parents for their continuous protections in my life and during my studies.

palavras-chave

Multimetodologia, *Soft Systems Methodology*, Indústria Iraniana, Sustentabilidade Energética, *Analytical Hierarchy Process*, *Unified Modeling Language*, Apoio à Decisão, Barreiras à Sustentabilidade Energética.

resumo

O objectivo desta tese é definir uma metodologia multidisciplinar, usando *Soft Systems Methodology*, com vista a analisar o sector da Indústria no Irão do ponto de vista de lançamento de novos projectos de sustentabilidade energética. Para a metodologia proposta uma indústria petroquímica, uma pequena empresa do ramo automóvel e uma empresa que faz consultoria em energia são analisadas. A indústria petroquímica surge como a que potencialmente terá maiores ganhos do ponto de vista de poupança energética. Para além de SSM, o modelo AHP, a *framework* MCIR, diagramas UML e um estudo de viabilidade financeira são usados para o desenvolvimento da metodologia proposta. O modelo AHP usado neste estudo permite trabalhar dados qualitativos de uma forma quantitativa. A *framework* MCIR classifica as barreiras interrelacionadas e identifica as necessidades de sustentabilidade energética na indústria. Métodos de análise financeira são usados na metodologia proposta e, por último, diagramas UML mostram o processo de informação.

keywords

Multimethodology, Soft Systems Methodology, Iranian Industry, Energy Sustainability, Analytical Hierarchy Process, Unified Modeling Language, Decision Making, Energy Sustainability Barriers.

abstract

The aim of this essay has been to try out Soft Systems Methodology in development of a multidisciplinary framework to launch energy sustainability in Iranian industry sector. A petrochemical industry, one small sized company from the automobile industry and an energy service company are studied due to their diversity in conditions. The petrochemical industry is recognized to possibly have more gains in terms of improving energy consumption. Beyond SSM, the AHP model, MCIR framework, UML, and financial feasibility study methods are used in the development of CSEL framework. The AHP model applied in this study transforms qualitative data into quantitative decision making results. The MCIR framework classifies the barriers which have interrelated nature and identifies the gaps of energy sustainability in industry. NPV and SPB of financial analysis methods are applied in this framework and finally UML diagrams depict the information process in the latter subsystem of this framework.

Acronyms

SE – Systems Engineering

OR – Operation research

SSM – Soft Systems Methodology

SSM (p) – Soft Systems Methodology (process)

SSM (c) – Soft Systems Methodology (content)

CSEL – Compound Sustainable Energy Launching

EE – Energy Efficiency

MCIR – Motivation-Capability-Implementation-Results

VA – Voluntary Agreement

EMS – Energy Management System

ESCOs – Energy Service Companies

MNCs – Multi-national Companies

CSR – Corporate Social Responsibility

CR – Consistency Ratio

CI – Consistency Index

RI – Random Index

RD – Root Definitions

CATWOE – Client, Activity, Transformation, Worldview, Owner, Environment

I/T/O – Input, Transformation, Output

UML – Unified Modeling Language

EDR – Energy Demand Reduction

RET – Renewable Energy Technologies

PM – Preventive Maintenance

SCM –Supply Chain Management

R&D – Research and Development

DM – Decision Maker

AHP – Analytical Hierarchy Process

BAT – Best Available Technology

CAT – Current Available Technology

IRI – Islamic Republic of Iran

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Chapter 1. Introduction

Industry contributes directly and indirectly (through consumed electricity) about 37% of the global greenhouse gas emissions (Worrell, Bernstein, Roy, Price, & Harnisch, 2008) and industrial energy use accounts for approximately one-third of the world's energy demand (Chai & Yeo, 2012). Iran is an energy-rich country possessing 11 percent of global oil reserves and 15.3 percent of global natural gas reserves. Ranked 2nd among OPEC and with a potential for natural gas exports to Europe and Asia. Iran also plays a significant role in the world energy market and the global economy. However, Iran's rapidly growing own energy consumption (about 6 percent per year for the past 30 years) has raised concerns about the country's ability to continue to export oil in the next decade (Moshiri, 2013). The main driving forces behind the rising trend of energy consumption are economic growth (5 percent for the past 40 years) and population growth (about 2 percent), and heavily subsidized energy markets (12 percent of the GDP)("Central Bank of Iran, Statistics," 2012; Moshiri, 2013). Rapid economic development means industrialization, urbanization and motorization (Ruehl & Giljum, 2011). A stylized pattern of economic development shows energy intensity rising as the economic structure shifts from low energy intensive agriculture to intensive activities in industry, and then falling again as the economy shifts to the less energy intensive service sector (Ruehl & Giljum, 2011). Iran is reducing its dependence on oil by developing an "economy of resistance" to circumvent international sanctions ("Iran develops 'economy of resistance' - FT.com," 2012). In a decree issued Feb. 19, Iran's Supreme Leader Ayatollah Ali Khamenei introduced the general policies of Iran's "resistance economy." One of the key objectives presented in this document is: utilization of subsidy reforms to optimize energy consumption in the country, increase employment and domestic production and promote social justice (Khajehpour, 2014).

In essence, three major factors related to human activity affects the environment, population growth, material use, and energy use (Thollander & Palm, 2012). According to Thollander & Palm (2012) shifting human activity based environmental problems from being local problems to global scale problems calls for a shift from "end-of-pipe" solutions to proactive means. The sustainability principles are solutions to face these challenges in the world. Yet, these principles must be adopted in line with current business activities and global societal trends (Nattrass, 2013). If the sustainability principles are adopted too rapidly, industrial organizations risk bankruptcy. However, if industrial organizations direct their operations step-by-step toward improved sustainability, they will reap tremendous economic benefit (Thollander & Palm, 2012).

According to World Commission on Environment and Development, Sustainable development is development which meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland, 1987). In the extensive discussion and use of the concept since then, there has generally been recognized three aspects of sustainable development namely: economic, environmental, and social (Harris, 2000).

With this in mind Sustainable Energy as a subset embodies the triple aspects of sustainable development. Among different definitions that have already been proposed in this subject

REEEP website of Sustainable Energy Regulation Network proposes a closer definition to that of sustainable development as following:

“Effectively, the provision of energy such that it meets the needs of the present without compromising the ability of future generations to meet their own needs. (See Sustainable Development). Sustainable Energy has two key components; renewable energy and energy efficiency” (Lemaire, 2004). The World Energy Council’s definition of energy sustainability is based on three core dimensions - energy security, social equity, and environmental impact mitigation. The development of stable, affordable, and environmentally-sensitive energy systems defies simple solutions. These three goals constitute a ‘trilemma’, entailing complex interwoven links between public and private actors, governments and regulators, economic and social factors, national resources, environmental concerns, and individual behaviors (“2012 Energy Sustainability Index,” 2012).

If we want to illustrate the sustainability, energy sustainability and industrial energy sustainability in system layers Figure 1.1 may be helpful. The industrial energy sustainability, the level which is focused in this work is subset of general energy sustainability that includes two other subsets of transportation energy and household energy. The two aspects of economic and environmental are addressed in this dissertation by CSEL model.

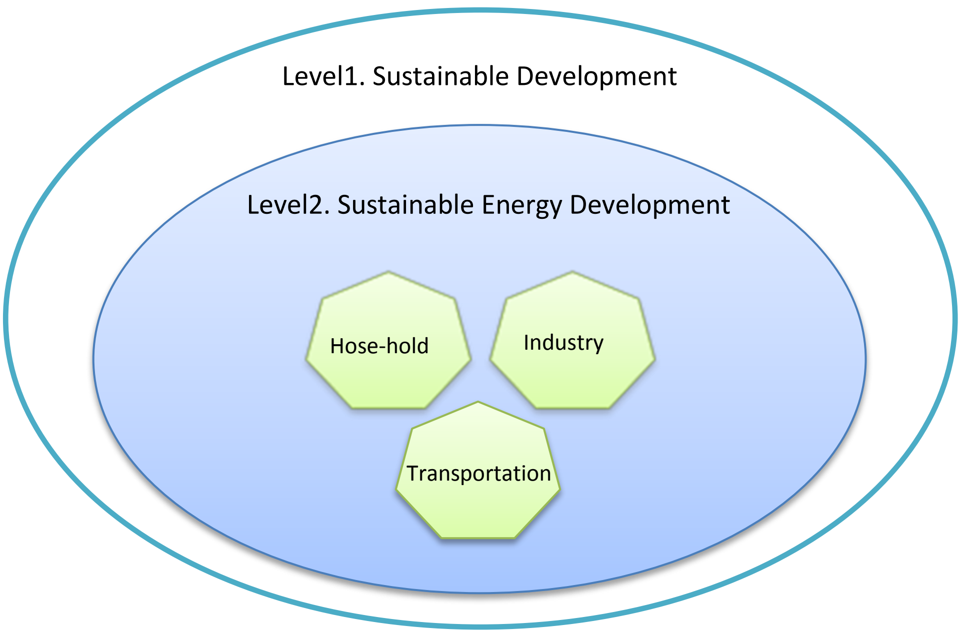


Figure 1.1 System levels of sustainability

Mingers (1996) recommended multi-methodology concept for the first time. “It outlines a number of different possibilities for combining methodologies, and considers why such a development might be desirable for more effective practice, in particular by focusing upon how it can deal more effectively with the richness of the real world and better assist through the various intervention stages” (Mingers & Brocklesby, 1997). This work also applies a multi-methodology concept to deal with the richness of the real world. To do so primarily it is required that the complicated situation of the Iranian industrial sector be addressed by a suitable system thinking methodology which, as a holistic method, prepares a basis to investigate all other recommended methods for their efficacy, efficiency and effectiveness in the whole multi-methodology structure. This procedure leads to an appropriate framework for addressing energy sustainability deployment. Soft Systems Methodology (SSM) seems to prepare the best cyclical learning base for structuring such framework and later on helps in deployment of sustainability initiatives inside the industrial companies. The including methods should contain suitable methods for analyzing the interest in different stages and rank the hierarchical preferences of stakeholders. Then it is needed a method to classify barriers, illustrate the gaps and to send signals for policy makers of the company and those of the higher decision making level, in government or ESCOs for example. Finally a financial method has to be structured to help decision makers choose the appropriate alternative among different energy solutions with the purpose of triggering and pursuing the energy sustainability launching process inside the companies, with taking into consideration the social situation and interests in that system. Although these different methods may individually fulfill the respected expectations but also it is important to consider the coherency and consistency among them in structuring a whole under the name of CSEL framework.

For the second chapter it will be attempted to specifically describe the system thinking concept and SSM structure to simplify a step by step implementation of this method for energy managers and system managers those who are active in energy systems improvement and management. The author will try to bring practical examples especially for each activity of four principle activities of SSM.

Chapter three of this study proposes the methodologies that are considered to be useful in structuring the Compound Sustainable Energy Launching (CSEL) framework. The author believes that Unified Modeling Language UML potentially is a suitable method in preparing the framework for software development purposes. Also two methods of AHP and MCIR framework will be studied in this chapter to evaluate the compatibility of them in the CSEL framework.

Finally chapter four structures the CSEL model and brings some examples from petrochemical industry for comprehension of the model. The conclusion, limitation and future work in chapter five will clarify the way that has been paced and the path which is in front.

Chapter 2. System Thinking and Modeling Language

2.1. System and System thinking

Learning from books or lectures is relatively easy, at least for those with academic bent, but learning from experience is difficult for everyone (Checkland, 2000). Life is more different than the school, in life we have to state the answer and the question. Gaining awareness of how we think is the first step in creating. When we state problems correctly the answer should follow, in other words, the way we state a problem immediately constrain the answers. David Bohm in its book "unfolding meaning" (Bohm, 1985) mentions that we will never correct the fragmentation in our society until we correct the fragmentation in our thinking.

In systems science, it is argued that the only way to fully understand why a problem or element occurs and persists is to understand the parts in relation to the whole (Banathy, 1996). Reductionist thinking is not synonymous with thinking, it is subset of thinking. Traditionally analysis focuses on separating the individual pieces of understudy things. As a matter of fact the term "Analysis" comes from the root meaning "to break into constituent parts" ("Analysis dictionary definition | analysis defined," 2014). At a very basic level, a system is simply a set of interdependent components interacting to achieve a common specified goal (Henriksen, Dayton, Keyes, Carayon, & Hughes, 2008). For instance learning process in our brain is not through the change in the cells of the brain but it is through the increasing of interconnection between them. Similarly organizations learn by improving the interactions of their elements. System thinking requires that we shift our mind from event orientation (linear causality) to focusing on internal system structure (circular causality) (Boulding, 1956).

Systems have several defining characteristics that are as following:

- Every system has a purpose within a larger system. Example: to generate new ideas and features for the organization.
- All of a system's parts must be present for the system to carry out its purpose optimally.
- A system's parts must be arranged in a specific way for the system to carry out its purpose.
- Systems change in response to feedback. The word feedback plays a central role in systems thinking. Feedback is information that returns to its original transmitter such that it influences that transmitter's subsequent actions.
- Systems maintain their stability by making adjustments based on feedback. Example: Your body temperature generally hovers around 98.6 degrees Fahrenheit. If you get too hot, your body produces sweat, which cools you back down.
- It emphasizes wholes rather than parts, and stresses the role of interconnections—including the role we each play in the systems at work in our lives.
- It emphasizes circular feedback (for example, A leads to B, which leads to C, which leads back to A) rather than linear cause and effect (A leads to B, which leads to C, which leads to D and so on).
- It contains special terminology that describes system behavior, such as reinforcing process (a feedback flow that generates exponential growth or collapse) and balancing

process (a feedback flow that controls change and helps a system maintain stability) ("Systems thinking and its foundation in the field of system dynamics," 2013).

According to Checkland and Poulter (2010), survival of system through time requires (Checkland & Poulter, 2010):

- Communication processes
- Control processes
- Structure in layers
- Emergent properties of system as a whole.

Checkland believes that the emergent properties of a whole are its purposefulness "A logically linked set of activities constitute a whole – its emergent properties being its purposefulness"(Checkland & Poulter, 2006). There are different ways of viewing a system:

1. Hard Systems Approach (Systems Analysis, Systems Engineering, Operations Research)
2. Soft Systems Approach (Soft Systems Methodology, Soft OR).

Table 2.1 shows some differences between these systems:

Table 2.1 Soft vs Hard Systems (Cairns, 2006)

Hard systems	Soft Systems
Problem has a definite solution	There are many problems to be solved
Problem has a number of achievable goals	Goals cannot be measured
They answer the 'how' question	Emphasis is placed on 'what' as well as 'how'
Has a deterministic complexity	Has a unpredictable, non-deterministic, non-definable complexity
Likely to have defined parameters for failure	Less easily dealt with

SE is an archetypal example of what is now known as 'hard' systems thinking. Its belief is: the world contains interacting systems. They can be 'engineered' to achieve their objectives. This is the stance not only of SE, this thinking also underpins classic Operational Research, RAND Corporation 'systems analysis', the Viable System Model, early applications of System Dynamics and the original forms of computer systems analysis (Checkland & Poulter, 2010).

In SE, the word 'system' is used simply as a label for something taken to exist in the world outside ourselves. The taken-as-given assumption is that the world can be taken to be a set of interacting systems, some of which do not work very well and can be engineered to work better (Checkland, 2000).

But existence of conflicting worldviews is the missing consideration in all hard systems approaches, while all social interactions are characterized with different conflicting worldviews. In order to incorporate the concept of worldview into the approach being developed, it was necessary to abandon the idea that the world is a set of systems. In SSM the (social) world is taken to be very complex, problematical, mysterious, and characterized by clashes of worldview. It is continually being created and recreated by people thinking, talking and taking action. However, our coping with it, our process of inquiry into it, can itself be organized as a learning system (Checkland & Poulter, 2010).

According to Checkland & Poulter (2010) in SSM the notion of systemicity ('systemness') appears in the process of inquiry into the world, rather than in the world itself. Yet Khisty (1995) in its paper compares the two methodologies perfectly in Table 2.2.

Table 2.2 Comparison of HSM and SSM (Khisty, 1995)

Attributes	HSM	SSM
Orientation	Systematic goal seeking	Systemic learning
Roots	Simplicity paradigm	Complexity paradigm
Belief	Systems can be "engineered"	Systems can be explored
Belief	Models are of the world (ontologies)	Models are intellectual constructs (epistemologies)
Belief	"Closure" is necessary	"Inquiry" is never ending
Belief	"Finding" solutions to problems	"Finding" accommodation to issues
Human content	Nonexistent	High
Question(s)	How?	What and how?
Suitability	Well-structured problems	Ill-structured problems

Examples of areas in which systems thinking has proven its value include:

- Complex problems that involve helping many actors see the "big picture" and not just their part of it.
- Recurring problems or those that have been made worse by past attempts to fix them.
- Issues where an action affects (or is affected by) the environment surrounding the issue, either the natural environment or the competitive environment.
- Problems whose solutions are not obvious ("Systems thinking and its foundation in the field of system dynamics," 2013).

2.2. Soft Systems Methodology

Since SSM has its roots in action research this is a quite natural way and almost mandatory method of conducting this study (Checkland & Poulter, 2006). Essentially action research deals with solution of human practical problems in real world situations, the same thing that is expected from SSM with some differences in perception of the words 'Problem' and 'Solution'. 'Problem' in action research suggests that there is a clearly defined problem at hand, which in SSM there isn't. Also 'solution' in action research implies that the problem will be fixed forever which is very wrong when referring to human systems and organizations in SSM. Checkland and Poulter (2010) summarize the account of SSM as following:

“SSM is an action-oriented process of inquiry into problematical situations in the everyday world; users learn their way from finding out about the situation to defining/taking action to improve it. The learning emerges via an organized process in which the real situation is explored, using as intellectual devices - which serve to provide structure to discussion - models of purposeful activity built to encapsulate pure, stated worldviews”.

Each situation perceived as problematic has both ‘hard’ and ‘soft’ elements. SSM does not differentiate between soft and hard problems; it merely provides a different way of dealing with situations perceived as problematic. So hardness and softness is not intrinsic specification of one problem situation, but is an aspect of the method that problems are being explored under specific conditions (“References - Project MEME,” 2014).

One important and obvious key thought about day-to day life problem situations is that the situation itself is not static and is being continuously created and changed. Moreover the complexity and unclear specification of the problem situation in SSM results in an organized learning system in SSM that leads to new knowledge and insight concerning the problem situation, further ideas and ongoing learning process. Figure 2.1 shows a schematic SSM learning cycle.

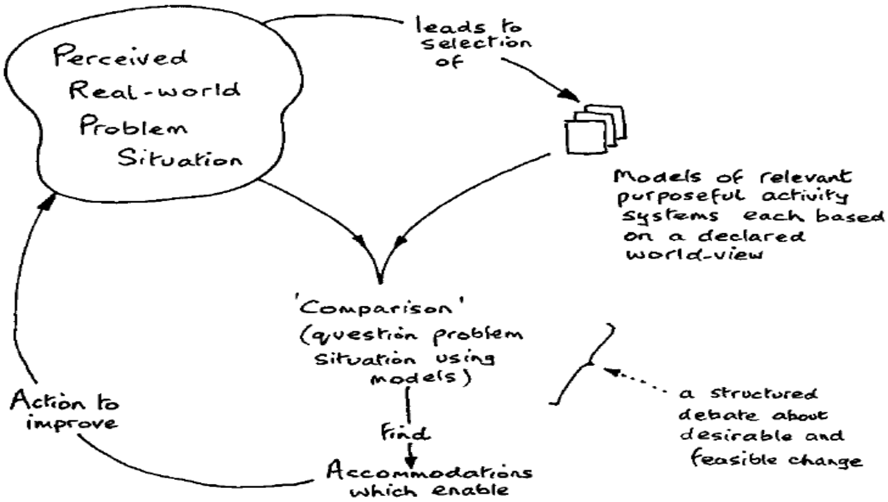


Figure 2.1 the inquiring learning cycle of SSM (Checkland, 2000)

According to the Checkland (2000), a need for getting away from thinking in terms of some real-world systems in need of repair or improve, plus existence of many interpretation of any declared purpose are another key thoughts which dictated the overall shape of SSM development.

2.2.1. Historical perspective of SSM

Regarding the development of the SSM we have to mention that the way in which it is now is very different from the view of it in the 1970th. Here is given a summary of SSM development along the conceptive timeline. Besides the references mentioned Checkland’s thirty year retrospective study (2000) is used to characterize this section.

1981- Seven Stages Model: Seven activities in circular learning process. The advantage of this model is the ease of understanding as a sequence, which unfolds logically. The distinguishing line between upper, day-to-day life, world and lower, system thinking about everyday life, world is one of distinguishing features of this model.

1988 – Two Streams Model: In this model the action is more facilitated rather than the Seven Stages Model. Moreover since Ideas are not usually enough to trigger action, culture of the situation is gained and understood in this model. So SSM as an approach embody:

- A logic-based stream of analysis (via activity models)
- A cultural and political stream.

With this in mind two streams model analyze the problem situation in two streams with the aim to improve it; a logic base stream of analysis, and stream of cultural analysis.

1990 – Four Main Activities model: In comparison to seven stages model this approach is more flexible and comparing to two streams model this model has more formal air, besides it is iconic rather than descriptive and subsumes the cultural stream of analysis in four main activities, or the SSM cycle.

According to Checkland and Poulter (2010) these activities are:

1. Finding out about the initial situation which is seen as problematical.
2. Making some purposeful activity models judged to be relevant to the situation; each model as an intellectual device, being built on the basis of a particular pure worldview.
3. Using the models to question the real situation. This brings structure to a discussion about the situation, the aim of the discussion being to find changes which are both arguably desirable and also culturally feasible in this particular situation.
4. Define/take the action to improve the situation.

It is important to be mentioned that the learning cycle (Figure 2.1) is in principle never-ending.

2.3. SSM Process

According to Checkland (2000) the changes, whether additions or deletions, were never made by just sitting at desks being academic, rather they are always the result of experiences in using the approach in a complex world. Hereby the process of SSM is being described in a sequence but it doesn`t mean that this cycle of activities (1) to (4) will go on in a sequentially steps. Once SSM investigations initiated from finding out about problem situation, the activity will go on simultaneously in more than one of the steps. Figure 2.2 shows a typical pattern of activity during an SSM investigation.

Figure 2.2 a typical pattern of activity during an SSM investigation (Checkland & Poulter, 2010)

A basic outline of SSM process is shown in Appendix A and following describes the four main activities model of Checkland mentioned in the previous section.

2.3.1. Finding out about the Problem Situation

- Making rich pictures;
- Carrying out three kinds of inquiry, known as; Analysis One (intervention itself), Analysis Two (social analysis/ what kind of 'culture' is this?), and Analysis Three (political analysis/ what is the disposition of power here?).

2.3.1.1. Making Rich Pictures

The aim of this part is to make drawings to indicate the many elements in any human situation, so that a person who may be initially an outsider will be familiar with what the situation presents. Multiple interacting relationships, that are the complexity of human affairs, are better expressed by pictures. Also pictures help to encourage holistic thinking rather than reductionist thinking about a situation, something which could be tabled as a basis for discussion. Users would say: (Checkland & Poulter, 2010)

'This is how we are seeing your situation. Could we talk you through it so that you can comment on it and draw attention to anything you see as errors or omissions?'

Users need to develop skills in making 'rich pictures' in ways that they are comfortable with them and also as natural as possible for them. A crucial skill in developing a picture is selection of the key features of a situation. According to Checkland and Poulter (2010) the aim in making a rich picture is to capture informally:

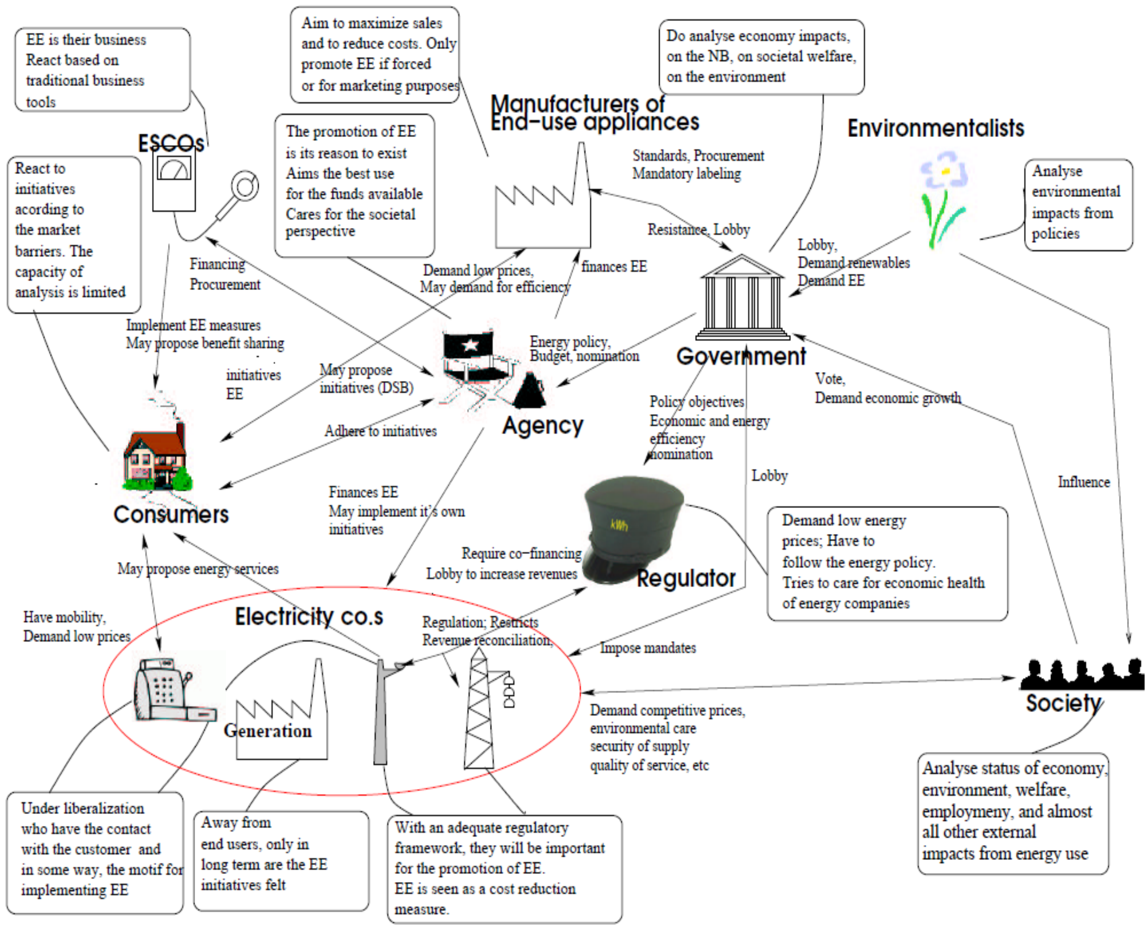
- The main entities
- Structures and viewpoints in the situation
- The processes going on
- The current recognized issues and any potential ones.

Again according to the same reference, the initiating step for drawing a rich picture is assembling the knowledge of a situation by:

- Talking to people
- Conducting more formal interviews
- Attending meetings
- Reading documents & etc.

After assembling the knowledge of a situation comes along beginning to draw simple pictures that become richer as inquiry proceeds and this cycle continues in an iterative manner. This picture can lead to better-than usual level of discussion because not only can be taken in as a whole but also it displays the multiple relationships (Checkland & Poulter, 2010).

Figure 2.3 shows a rich picture concerning energy efficiency initiatives in Portuguese society level that is designed by Neves et al. (2002). In this picture the main entities of industrial section in country level, with interrelations among them are depicted. The study is used to structure the first sub-system of CSEL framework that will be discussed in this work.



Legend:
EE = Energy Efficiency initiatives
NB = National Budget

Figure 2.3 A Rich-picture for Energy Efficiency Actors (Neves, Martins, Antunes, & Dias, 2002)

2.3.1.2. Analysis One, Two and Three

Analysis One, The intervention itself

Never imagine that any methodology can itself lead to 'improvement'. Three elements – the methodology, the use of the methodology by a practitioner and the situation – are brought together in a particular relationship. SSM's 'Analysis One', then, consists of thinking about the situation asking: Who are in the roles 'client' and 'practitioner'? And who could usefully be included in the list of 'issue owner'? Checkland found three roles as key roles that are always present and defined them as following (Checkland & Poulter, 2006):

1. There was some person (or group of persons) who had caused the intervention to happen, someone without whom there would not be an investigation at all – this was the role "client".
2. There was some person (or group of persons) who were conducting the investigation – this was the role "practitioner".
3. Most importantly, whoever was in the practitioner role could choose, and list, a number of people who could be regarded as being concerned about or affected by the situation and the outcome of the effort to improve it – this was the role "owner of the issue(s) addressed.

It should be considered that one person or group might be in more than one role. Also in every case the practitioner needs to make sure that the resources available to carry out the investigation are in line with its ambition.

So in analysis one also the roles have to be thought and defined having in mind that the person(s) in the ‘client’ role should be in the list of possible ‘issue owners’ but should not be the only one in the list. The list of issue owners prepared suggest for many world views that cause the richness of the inquiry to cope with the complexity of the real situation and suggest ideas for relevant activity models.

The practitioner can also be an issue owner, it depends how SSM is being used. Taking c for content, p for process, two kinds of use of the methodology are:

- SSM (c): To addressing the content of the situation
- SSM (p): Deciding how to carry out the investigation

Then one person can use the SSM in a manner that becomes beneficiary of the result of the process, as an issue owner, that would be a method helping him/ her in carrying out the investigation as a practitioner (see Figure 2.4 for better comprehension).

For instance in our case study deciding to use SSM to structure a framework which is suitable to address sustainable energy, is the use of SSM (p). And the use of SSM in addressing the actors of sustainable energy launching in the industrial zone and also identifying the decision making process for it, is SSM (c) use of methodology.

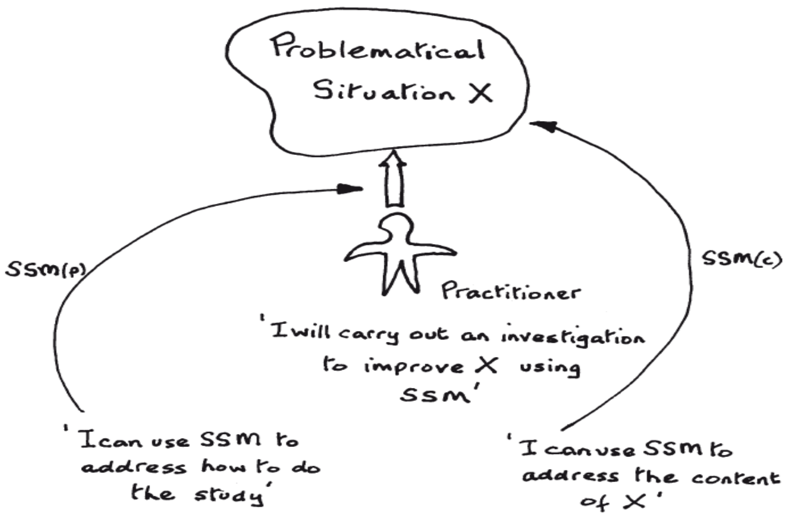


Figure 2.4 two kinds of SSM use by practitioner (Checkland & Poulter, 2010)

Analysis Two, Social

For any intervention and change in a human situation having a clear idea about what is being intervened is required. So having some sense of what social reality is taken to be is important especially for SSM as an action oriented approach. Analysis Two and Three was found in the autopoietic model teased out of the work of Vickers on `appreciative systems' (Checkland &

Casar, 1986; Checkland, 2000). Social reality is no 'reified entity' out there waiting to be investigated. It is to be seen as continuously socially constructed and reconstructed by individuals and groups (Checkland, 2000). An appreciative system model describes a social process and the dynamics of one appreciative system is depicted in Figure 2.5 in which the flux of events and ideas proceed in timeline while individuals and groups intervene in it by trying to recognize different aspects of this flux and change it according to their standards and this intervention defines new standards for further changes dynamically in the future cycles of intervention.

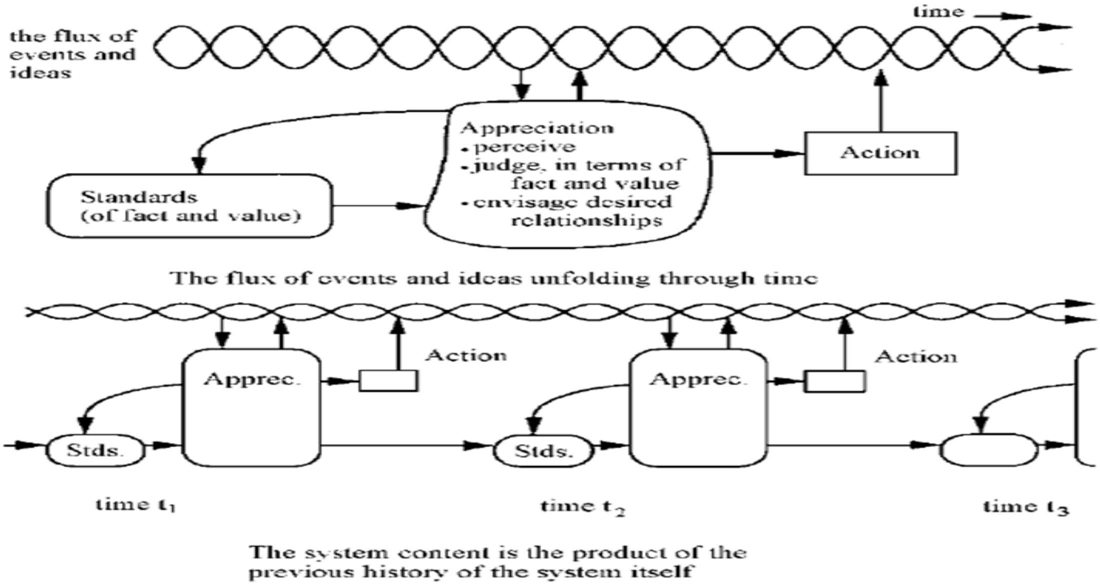


Figure 2.5 the structure and dynamics of an appreciative system(Checkland & Casar, 1986)

According to Checkland (2010) it is important to consider that a practical action which will improve a situation under investigation, and the proceeding changes have to be not only arguably desirable but also culturally feasible, so that the local 'culture' should be understood at a level beyond that of individual worldviews.

Each statement about culture of one situation has a sense of 'feeling' or 'flavor' for an individual that is taken to be its 'social texture'. SSM makes use of a particular model for getting a sense of the social texture of a society which is both simple and subtle. The subtlety of this model is because none of its elements are static; they change over time as the world moves on. Yet they are closely and dynamically related to each other. Each, over time, continually helps to create and modify the other two elements, as shown in Figure 2.6.

Here comes the definition of three elements of the model in summery according to what Checkland and Poulter (2010) defined:

- **Roles –** are social positions that mark differences between members of a group or organization. They might be recognized formally or informally.
- **Norms –** are the expected behaviors associated with, and helping to define, a role.
- **Values –** are the standards – the criteria – by which behavior-in-role gets judged.

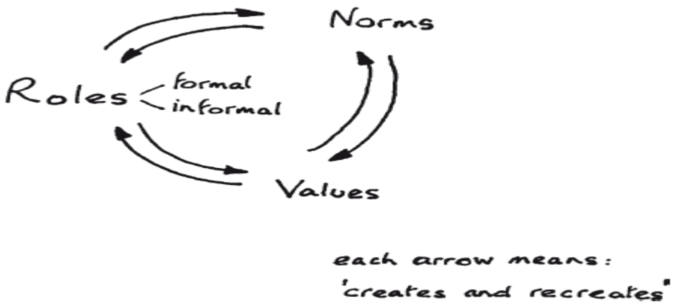


Figure 2.6 model used for getting the social texture sense of a human situation (Checkland & Poulter, 2010)

Analysis Three, Political

Analysis Three moves beyond the model of an appreciative system but is compatible with it. It covers one of the main determinants of the outcomes of a social process: the distribution of power in the social situation. This analysis is not based on an answer to the question: what is power but in turn works with the fact that everyone who participates in the life of any social grouping quickly acquires a sense of what you have to do to: influence people, to cause things to happen, to stop possible courses of action, or to significantly affect actions, the groups or members of it take.

Politics is part of culture that is not addressed directly in analysis two, while is always a powerful element in determining what is 'culturally feasible'. The model used in this analysis comes from basic ideas of: Aristotle. Accommodating different interests is the concern of politics; this entails creating a power-based structure within which potentially destructive power-play in pursuit of interests can nevertheless be contained. In order to encourage discussion of practical means of addressing power in an organization involved in change is used the metaphor of the 'commodities' which embody power.

Analysis three consists of asking: What are the 'commodities' which signal that power is possessed in this situation? Then: What are the processes, by which these commodities are obtained, used, protected, defended, passed on, relinquished, etc.? Figure 2.7 summarizes Analysis Three that is very similar to analysis two in procedure.

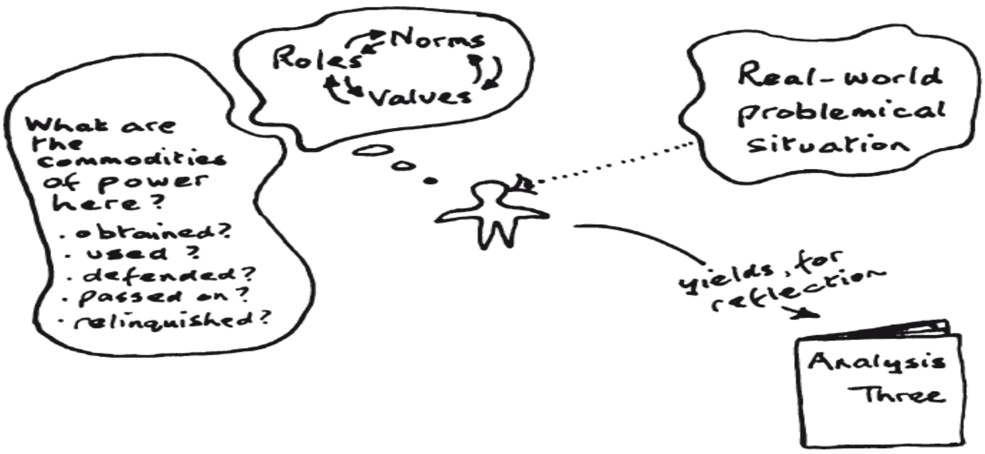


Figure 2.7 Analysis three of SSM (Checkland & Poulter, 2010)

Here are examples of what can be taken to be powerful in one group or organization:

- Knowledge
- A particular role
- Skills
- Charisma
- Experience
- Being clubbable
- Impudence
- Commitment
- Insouciance.

Also according to Checkland (2010) many commodities of power derive from information. Having access to important information, or being able to prevent others from having access to certain information, is a much-used commodity of power in most organizations.

As with analysis two, analysis three deals with elements which are continually being redefined as life moves on. Checkland (2000) also indicates that in analysis three, recent history of the organization or group can be questioned and/or illustrated in terms of commodities, all with the aim of finding out as deeply as possible: (1) How this particular culture `works'? (2) What change might be feasible and what difficulties would attend that change?

Finding out about problem situation will never finish by the end of analysis three, it goes on throughout a study, and must never be thought of as a preliminary task which can be completed before modeling state.

2.3.2. Building purposeful activity models

The purposeful activity models used in SSM are devices (intellectual devices) whose role is to help structure an exploration of the problem situation being addressed (Checkland, 2000). Such models could never be definitive descriptions of the real world. They model one way of looking at complex reality. They exist only as devices whose job is to make sure the learning process is not random, but organized, one which can be recovered and reflected on (Checkland & Poulter, 2010). According to Checkland (2000) the concept of model in scientific or technological thinking refers to some representations of some part of the world outside ourselves while models in SSM are not purport representations of anything in real situation, are relevant to debate about the situation perceived as problematic, and are simply devices to stimulate, feed, and structure that debate.

Checkland argues that SSM models also can be classified into two kinds of primary task models and Issue-based models. Primary task models map existing organizational structure, for example when R&D in a manufacturing company is to be carried out, while when organizations have to carry out corporately many more purposeful activities beyond organizational structure then models will be Issue-based models. For example in making a model based on the core idea of innovating in an industry, if innovation unit is not already set in the organization, then some activities taking place in the company and some were missing in the real situation, so that boundary did not coincide with the organizational boundaries of the existing departments. Do you think only in terms of models which map existing structure? This is the question by which primary task models and issue based models can be distinguished. In the following structural items will be explained which will help building models of purposeful activity according to the illustrated process of what is shown in Figure 2.8.

2.3.2.1. Root Definitions, CATWOE and Multi-level thinking

In selecting some hopefully relevant systems to model, there are in principle always a number of levels available, and it is necessary to decide for each root definition which level will be that of `the system', the level at which will sit the T of CATWOE (Checkland, 2000). In SSM three levels are taken into account, which are named: wider system, system, and higher system. Primarily the observer makes the choice which layer becomes the system level, then the higher level is wider system and one level below is the sub-system. For example if level three is system for the specific observer then level 2 is wider system and level 4 is sub-system level. System sits in T of CATWOE position, then A, Activities contributing to doing T, represent the sub-system. The wider system could stop T and stands in O position. Thinking in three levels can be expressed in another form of do P by Q in order to contribute to achieving R that expands the view of observer. It has to be mentioned that the choice of level is absolutely observer-dependent that means for example one system for an observer can be the subsystem of another observer.

T of CATWOE, which will be discussed later, represents transformation process that defines purposeful activity in SSM. In a Transformation what comes out is the same as what went in, but in a changed (transformed) state (Checkland, 2000). For example if the input of the Transformation process becomes “Need for X” then the output will be: “Need for x met”.

Checkland argues that in order to model a complex purposeful activity, a clear definition of it has to be modeled. Root Definitions (RD) in SSM, which are definitional statements, is constructed around transformation process (T).

In recent years, experience has shown the value of not only including CATWOE elements in definitions but also casting root definitions in the form of P,Q,R, which answers the three questions: What to do (P), How to do it (Q) and Why do it (R)? (Checkland, 2000). Checkland augments P and Q force the model builder to be sure that there is a plausible theory as to why Q is appropriate means of doing P. for example when in the purposeful activity one has to communicate (P) by letter writing (Q) then the model builder is forced to think if it is possible to replace it by more brutal but quicker way like communicating by email.

Before going to the RD stage the so called CATWOE of the situation should be identified.
According to Figure 2.9, the mnemonic CATWOE stands for:

- **C** – Customers who are the beneficiaries or victims of the particular system being studied.
- **A** – Actors who are responsible for doing the activities which make up T.
- **T** – Transformation that the purposeful activity bring about.
- **W** – Weltanschauung / Worldview, which represents the particular worldview that justifies the existence of the system under study.

- **O** – Owner who has the authority to stop the transformation process or change its performance measures.
- **E** – Environmental constraints that are external constraints that are taken as given.

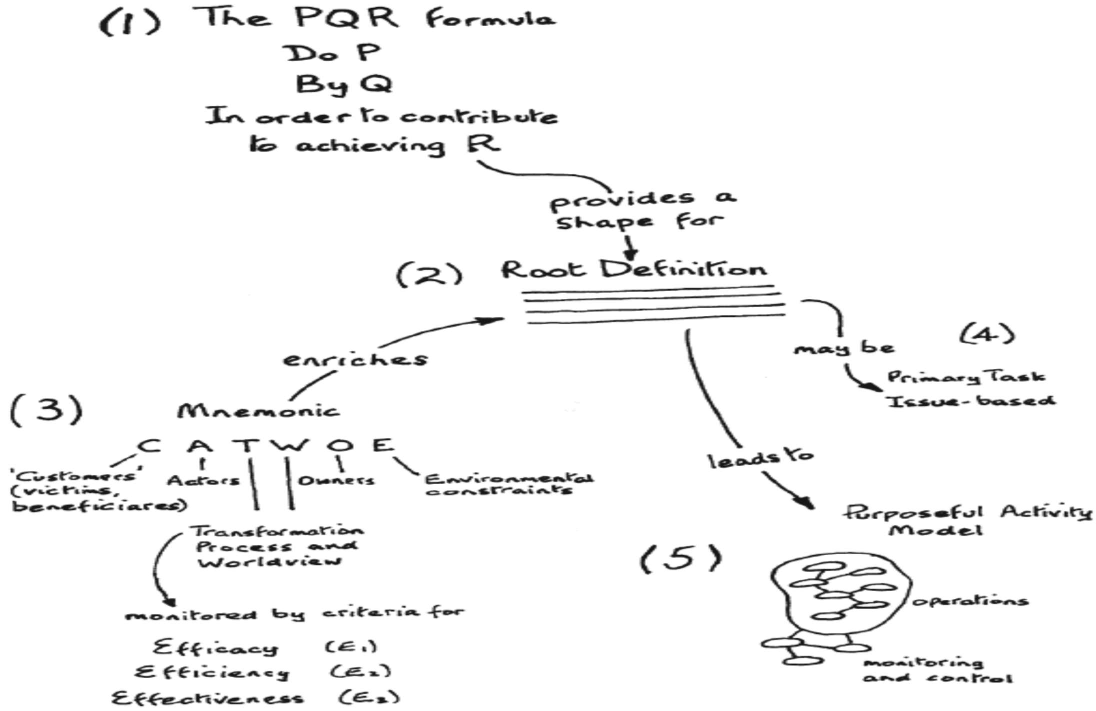


Figure 2.8 Guidelines which help with building models of purposeful activity (Checkland & Poulter, 2010)

Many people find it useful starting with T and W and then proceeding on other CATWOE elements. Now the RD can be defined according to what the mnemonic CATWOE means for special case.

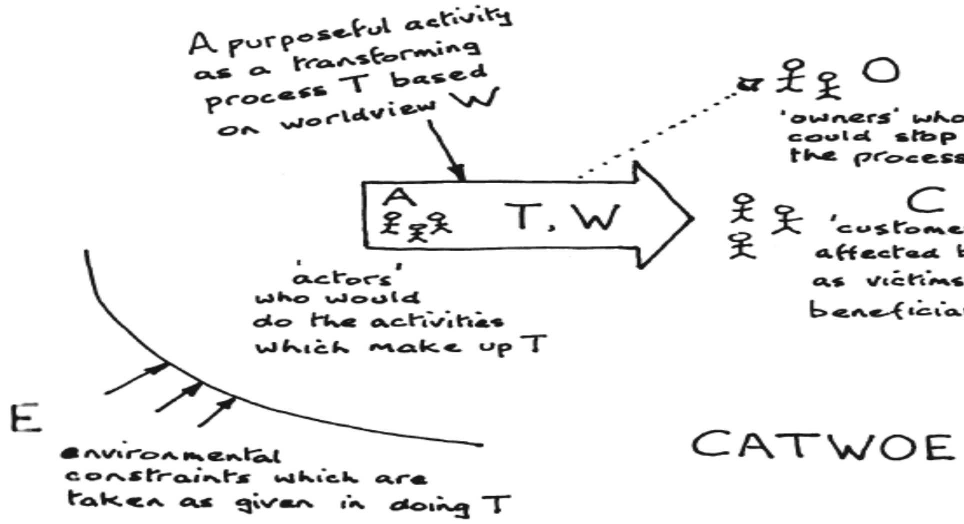


Figure 2.9 a generic model of any purposeful activity, which yields the mnemonic CATWOE (Checkland & Poulter, 2010)

An example which bustard et al (1999) brought in their work is related to a car park. Table 2.3 shows the related CATWOE, according to which the RD will be:

"A CCP plc owned system to facilitate use of a city shopping center on behalf of supermarket users arriving by car by using car park operators to provide parking spaces, taking account of the demand for spaces and the cost of space provision." (Bustard, He, & Wilkie, 1999)

Table 2.3 Root Definition components for a car park perspective (Bustard et al., 1999)

Components	Definition for car park
Customrs	Shopping centre users arriving by car
Actors	Car park operators
Transformation	Provide parking spaces
Weltanschauung	Facilitate use of a city shopping centre
Owner	City Car Parks plc (CCP)
Environment	The demand for spaces; the cost of space provision

Checkland argues that it can be useful to ask about methods to judge measurement of performance. "So our models, to use systems insights, need to be cast in a form which in principle allows the system to adapt in the light of changing circumstances" (Checkland, 2000). So that Checkland recommends that models of purposeful activity construct from a combination of two sets of activities:

1. Sets of linked activities (an operational system to carry out the T of CATWOE)
2. Set of activities which monitor the operational system and take control action if necessary.

For the second set of activities first of all the criteria, by which system performance will be judged, has to be defined, next a monitoring activity will be taken place and finally, provided that there was a need for 'taking control action', it will be carried out.

According to Checkland and Poulter (2010) three criteria are relevant in every case, and should always be named:

Efficacy – Criteria to tell whether the transformation T is working, in the sense of producing its intended outcome, i.e. criteria for efficacy.

Efficiency – Criteria to tell whether the transformation is being achieved with a minimum use of resources, i.e. criteria for efficiency.

Effectiveness – Criteria to tell whether this transformation is helping achieve some higher-level or longer-term aim, i.e. criteria for effectiveness.

These 'three Es' will always be relevant in building any model, but in particular circumstances other criteria might also apply, such as elegance (Is this beautiful transformation?) or ethicality (Is this a morally correct transformation?). The judgment depends on what criteria are needed (Checkland & Poulter, 2010).

Checkland (2000) argues that the combination of T, CATWOE, RD, and PQR prevents the thinking from being too narrow, and stimulates thoughts about whether or not to build other models. For example it might be decided also to model at the wider-system level, or to expand some of the individual activities in the initial model by making them sources of further root definitions.

2.3.2.2. Model Building

Checkland believes that model building by using merely the information already gathered from previous section about RD, CATWOE, three Es and PQR is not usually possible, but yet the constructor of the model should take care not to dominate real world knowledge.

The craft skill is to build a model using a background of real world knowledge without including features of typical practice which are not justified by the root definition, CATWOE, 3Es and PQR (Checkland, 2000).

Checkland (2000) proposes two logical templates for model building. The first template provides a step by step model building sequences for beginners of SSM appliers and the second one is a logical process model that is shown in Appendix B and depicts this process in a model which also contains justifying activities for accrediting the compatibility with I/T/O, $E_{1,2,3}$, CATWOE, and RD(PQR) definitions.

A sample activity model prepared by Checkland is available in Appendix C in which an alternative model analyzing activities is shown that separates criterion definition activity for effectiveness from criterion definition of other Es, so that different perspective of stakeholders like customers and house owner can be taken.

2.3.3. Exploring the Situation via Models

In development of the later stages of the SSM one important aspect that has to be considered is the ambiguity in contrast with the early stages. Checkland (2000) describes the early stages as circumstances in which a situation can be tentatively defined and explored, plausible `problem owners' named, `relevant' systems selected and models built. The later stages of a study using SSM cannot be pinned down and as sharply defined as the early stages (Checkland, 2000). Checkland believes that the underlying reason is that the language of 'Situation', 'Issues', and 'Problems' are subtle concepts that we must not reify them and they are themselves generated by human beings while no two people will see them in exactly the same way.

The main purpose of SSM models is defined as being utilized in discussions about situation and its improvement where without it, and a near-genius chairperson, lack of clarity and different voices will be addressing different issues, different levels, different timescales, and so on.

Checkland (2010) insists that although this stage is a comparison stage between real world problem situation and relevant model but this does not mean models are accounts of what we would wish the real world to be like because: "they are artificial devices based on a pure worldview, whereas human groups are always characterized by multiple conflicting worldviews (even within one individual!) which themselves change over time – sometimes slowly, sometimes remarkably quickly" (Checkland & Poulter, 2010).

In conducting the questioning from the problem situation it has to be mentioned that The possible questions to ask are unlimited and can be about activities, the dependence of one activity upon another, or performance measures by which one can judge the purposeful activity. Some examples of the questions that can be defined from the model are (Checkland & Poulter, 2010): 'Here is an activity in this model; does it exist in the real situation? Who does it? How? When? Who else could do it? How else could it be done?'... Etc. Or: 'This activity in the model is dependent upon these other two activities; is it like this in the real situation?'

Table 2.4 an example of questioning the model in a question chart (Patel, 1995)

Activity	Exist or not	Present mechanism	Measure of Performances	Recommendations	Comments
Know about the available teaching and learning resources	In part	Existing knowledge, but there is no constant flow of information regarding resources	State a variety of teaching and learning resources used	Establish procedures for gathering information about the available teaching and learning resources	I have some knowledge but there is no constant flow of information regarding resources
Select appropriate teaching and learning resources to use in a lecture	Yes	Individual choice from known resources	The effectiveness of teaching and learning resource used	Devise a mechanism for picking the appropriate teaching and learning resources	Use is made of those teaching and learning resources with which I am familiar
Know about the learning and absorption rates of students	No	None	None	Do this activity explicitly by, for instance, compiling and asking students to complete a questionnaire regarding their learning styles	This is done implicitly

In the learning cycle of SSM, three questioning forms of the situation are introduced namely: informally, via question charts, and via scenarios. In the informal approach of questioning problem situation a discussion is set up for situation improvement in the presence of models. In this method flipcharts are used to show up some relevant models for agenda on the wall. "This has been found useful in situations in which detailed discussion of the SSM approach is inappropriate or is not feasible for cultural reasons" (Checkland & Poulter, 2010). The second method is to create a chart matrix, which is a more formal approach and probably most commonly used. Checkland warns the participants not to plodding through every cell in the matrix and recommends a light-footed approach in turn. “Glancing quickly at many activities and questions, making judgments, and avoiding getting bogged down” (Checkland & Poulter, 2010). Table 2.4 shows an example of questioning the problem situation of an SSM application in real world process of teaching and learning. Chekland indicates that the relations in purposeful activity model also can be questioned in such question charts, the same similar to what is shown for activities of an example model (see Patel, 1995) in the table.

The third method of questioning of the situation is questioning via ‘scenarios’. In this method models are used as a basis for writing the circumstance of carrying out some purposeful action according to the model. Then this story, or scenario, will be compared with a real-world circumstance of similar procedure.

Finally Checkland (2010) suggests abandoning the present models in case of not resulting in energetic discussion and formulating “some more radical root definitions”.

2.3.4. The SSM Learning cycle – Defining Action to Improve

Now the process comes to keep under supervision watchfully the debate stage and to be ready to follow where the debate leads. Checkland (2000) warns not to expect predictable and tidy debate. The starting point to be considered is the possible changes of the situation and the second consideration in this stage is the consequences to be followed.

As discussion based on using models to question the problematical situation proceeds, worldviews will be surfaced, entrenched positions may shift, and possible accommodations may emerge (Checkland & Poulter, 2010). The changes entail such discussions are both arguably desirable and culturally feasible. Figure 2.10 illustrates the relation between accommodations, consensus and change. Checkland (2010) recommends in this stage focusing on what the concept of change can be for analytical purposes, and separates this concept into three parts of “making changes to structures; changing processes or procedures; and changing attitudes” (Checkland & Poulter, 2010). He ads on whereas structure changes is the most easy changes to make but any significant change in real situations will usually entail all three elements (Checkland & Poulter, 2010).

Checkland (2000) uncovers that according to experiences there are two common foci of the later stages of SSM, during which the driving principle is to bring the study to some sort of conclusion. The first focus is the original one and defines SSM as an action-oriented approach, seeking the accommodations which enable `action to improve' to be taken. The second focus, which is very prevalent in the great complexity characterizing the public sector, is a sense-making approach.

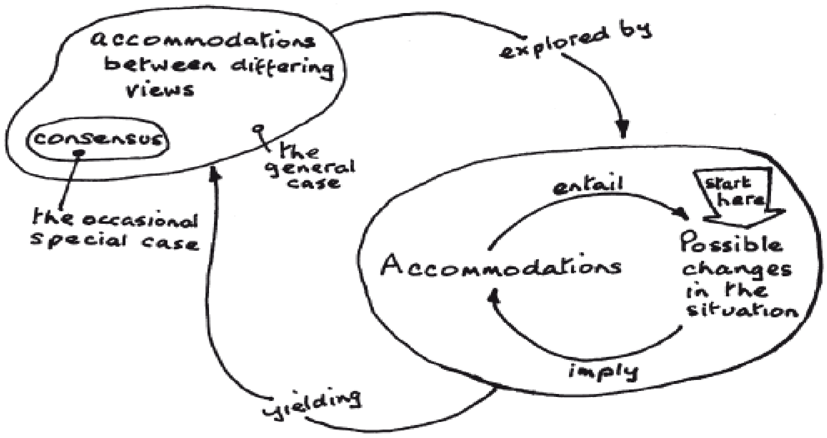


Figure 2.10 Seeking accommodations or (rarely) consensus by exploring implications of possible changes
(Checkland & Poulter, 2010)

In the first approach thinking about feasible and desirable change is structured. A most important feature of this is the need in human affairs to think not only about the substance of the intended change itself but also about the additional things you normally have to do in human situations to enable change to occur (Checkland, 2000).

To conclude the appropriate steps for action to improve the following should be performed. Firstly, it is started by exploring possible changes and noting reactions to them, and then proceeds on thinking richly about changes in human situations, followed by the step of separating the change concept into three parts, and finally thinking about additional requirements for implementation in human situation. Also it worth mentioning that according to Checkland (2000) sense-making may leads on to action being taken.

In 1992 the result of a survey were published, which was about SSM in practice based on respondents' answers to an open ended question, the applications that identified were as following (Mingers & Taylor, 1992):

- **Organizational design**: Restructuring of roles, design of new organizations, and creation of new organizational culture.
- **Information systems**: Definition of information needs, creating an IS strategy, knowledge acquisition, evaluation of the impact of computerization.
- **General problem solving**: Understanding complex situations, initial problem clarification.
- **Performance evaluation**: Performance indicators, quality assurance, monitoring an organization.
- **Education**: Defining training needs, course design, causes of truancy, analysis of language teaching.
- **Miscellaneous**: Project management, business strategy, risk management methodology, case for industrial tribunal, personal life decisions.

Chapter 3. Use of other methodologies within SSM

3.1. Unified Modeling Language and SSM

In developing a compound model for sustainable energy launching, a requirement for a modeling language as a translator, in order to translate the model composition to information system language, is encountered. “The Unified Modeling Language (UML) is a graphical language for visualizing, specifying, constructing, and documenting the artifacts of a software-intensive system.” (Giantdino, Booch, Rumbaugh, Jacobson, & Matter, 1998)

Five views of a system are discussed in UML but what are views of UML? “Similar to the business architecture, software architecture is described in a number of views, each of which depicts a specific aspect of the system. The views are not separate models; they are different perspectives on one or more specific aspect of the business. Combined, the views create a complete model of the business.” (Eriksson & Penker, 2000)

Bustard, He and Wilkie (1999) named these five views of UML as: Use-case (external user perspective), Logical (internal system design), Component (architectural constituents), Concurrency (describing mechanisms of co-ordination between independently processing system parts) and Deployment (mapping system parts onto a physical architecture).

Each of these views involves structural modeling (modeling static things), as well as behavioral modeling (modeling dynamic things). Together, these different views capture the most important decisions about the system. Individually, each of these views lets you focus attention on one perspective of the system so that you can reason about your decisions with clarity (Giantdino et al., 1998).

Furthermore, a series of diagrams are developed form these views. According to Erikson and Penker (2000), UML has nine predefined diagrams:

- Class diagram: Describes the structure of a system. The structures are built from classes and relationships. The classes can represent and structure information, products, documents, or organizations.
- Object diagram: Expresses possible object combinations of a specific class diagram. It is typically used to exemplify a class diagram.
- Statechart diagram: Expresses possible states of a class (or a system).
- Activity diagram: Describes activities and actions taking place in a system.
- Sequence diagram: Shows one or several sequences of messages sent among a set of objects.
- Collaboration diagram: Describes a complete collaboration among a set of objects.
- Use-case diagram: Illustrates the relationships between use cases. Each use case, typically defined in plain text, describes a part of the total system functionality.
- Component diagram: A special case of class diagram used to describe components within a software system.
- Deployment diagram: A special case of class diagram used to describe hardware within a software system.

These diagrams capture the three important aspects of systems: structure, behavior, and functionality (Eriksson & Penker, 2000).

When another system language is been used to develop CSEL framework, which will discussed later in this work, the story comes to this point that how can we mix these two methods with each other? What exactly they do in respect to the model development? What are their differences in terms of their roles on model development? Or in a brief sentence are they mutually supportive or mutually exclusive? Trying to answer these questions and some more is what Bustard, He and Wilkie (1999) discussed in their work. They believe SSM and Use-case of UML have one common function; they both try to identify activities that an organization must perform on its way for goal achieving.

Checkland's Soft Systems Methodology (SSM) can be used to support strategic planning for business improvement. This involves the development of system models to identify the activities that an organization must perform to meet its goals. Jacobson's Use-case modeling in the Unified Modeling Language (UML) is a requirements engineering technique that similarly leads to the identification of system activities (Bustard et al., 1999).

Also they believe that the difference of this role is the perspective that the requirements are looked from, in other words Use-case modeling is driven by the needs of the system's 'users' while the SSM is driven by the needs of the system itself or the inherent goals of the business.

Since the Use-case view is the main reference base used throughout the UML modeling activity and influences all other views it is used in the work that Bustard et al (1999) done in a comparison stage with SSM. So, once an initial set of Use-cases has been identified and documented (during requirements analysis), they facilitate step-by-step development right through to the delivery of the completed software system (Bustard et al., 1999).

3.1.1. Use-case diagram

A set of 'Use-cases' are utilized to define a system in Use-case modeling. In this modeling 'Actors' are agents, can be humans or otherwise, that trigger the system to work. When implementing the system, collaboration happens amongst these Use-cases to carry out each of them.

Giantdino et al. (1998) describe Use-case, which is subset of Use-case diagrams, separately in detailed manner in their work and give a principle definition to the Use-case that continues with describing a number of important parts of this definition. A use case specifies the behavior of a system or a part of a system and is a description of a set of sequences of actions, including variants, that a system performs to yield an observable result of value to an actor (Giantdino et al., 1998). The definitional parts include:

- A Use-case as a description of a set of sequences: each sequence represents the interaction of the things outside the system (its actors) with the system itself (and its key abstractions). Use-case represents a functional system requirement as a whole.
- Interaction of actors and the system, whether humans or automated systems.
- Variants of a Use-case: Specialized versions of other Use-cases, Use-cases that are included as parts of other Use-cases, and those that extend the behavior of other core

Use-cases. These common reusable behaviors can be factored by organizing them according to these three kinds of relationships.

- A use case carries out some tangible amount of work.

Another aspect of Use-case models is the level at which they are used. In fact there is no need to specify implementation of each Use-case in detail and it's just enough to describe what we expect the system to be like to communicate well with the system developer as a user and take into consideration the more risky level. The great thing about this is that it lets you (as an end user and domain expert) communicate with your developers (who build systems that satisfy your requirements) without getting hung up on details even though those details will come, but use cases let you focus on the issues of highest risk to you (Giantdino et al., 1998).

Use-case can be applied to the whole understudy system or also can be applied to part of the system including subsystems and even individual classes and interfaces. Use cases applied to subsystems are excellent sources of regression tests; use cases applied to the whole system are excellent sources of integration and system tests (Giantdino et al., 1998). In Chapter Four of this work Use-case is applied to one sub-system of CSEL framework.

According to the Giantido et al. (1998) Use-case has to be explained in accompaniment with some features namely 'names' of Use-cases, 'actors', 'flow of events', 'Scenarios', and 'Collaborations'.

- An actor represents a coherent set of roles that users of use cases play when interacting with these use cases.
- A Use-case flow of events: one Use-case has an outside view which means it describes what a system does not how it does it (which is an inside view).
- A 'scenario' is a specific sequence of actions that illustrates behavior and basically is one instance of a use case; moreover each Use-case may expand out to several dozen scenarios. For each use case, you'll find primary scenarios (which define essential sequences) and secondary scenarios (which define alternative sequences).
- Use-cases and Collaboration: In Use-case implementation, a society of classes and other elements is created that work together to implement the behavior of a use case. This society of elements, including both its static and dynamic structure, is modeled in the UML as 'Collaboration'. A Use-case can be explicitly specified by 'Collaboration'.
- Organizing Use-cases: The first method is grouping Use-cases in packages, and the second method is organizing via generalization, include and extend relationships.

Use case diagrams are one of the five diagrams in the UML for modeling the dynamic aspects of systems (activity diagrams, statechart diagrams, sequence diagrams, and collaboration diagrams are four other kinds of diagrams in the UML for modeling the dynamic aspects of systems). (Giantdino et al., 1998) A use case diagram acts as a focus for the description of user requirements. It describes the relationships between requirements, users, and the major components ("UML Use Case Diagrams: Reference," 2014). They commonly contain Use-cases, Actors, and Relationships (dependency, generalization, and association).

A dependency is a relationship that signifies that a single or a set of model elements requires other model elements for their specification or implementation. ("Use Case Diagram - UML 2 Diagrams - UML Modeling Tool," 2014) Moreover in Use-case diagrams the system (or subsystem boundaries are shown with a rectangular shape like Figure 3.1.

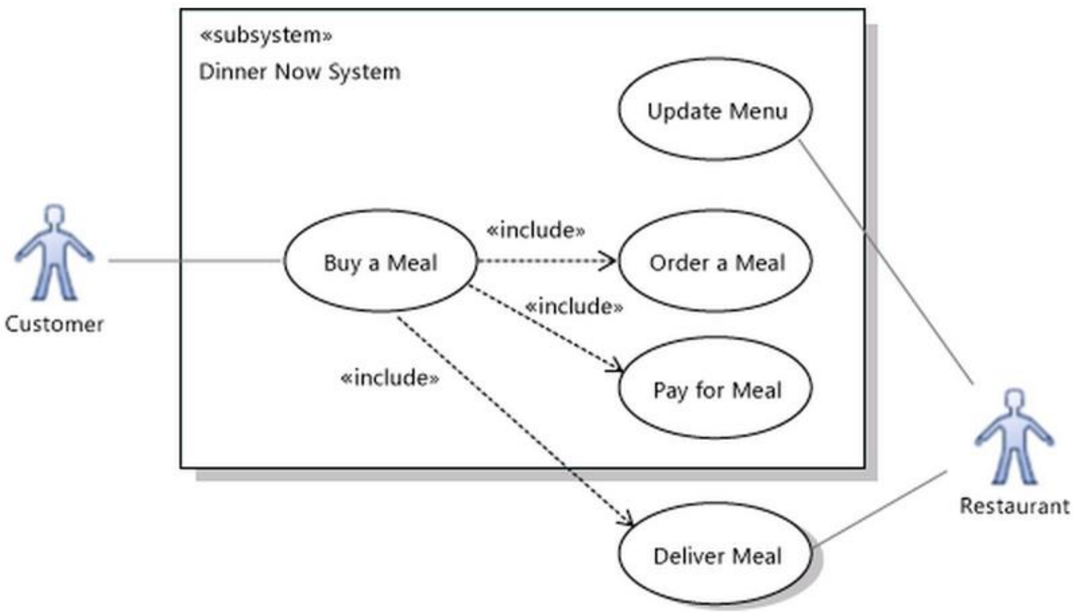


Figure 3.1 Actors, Use-cases and subsystems ("Modeling User Requirements," 2014)

In their work, Bustard, He and Wilkie examine the relationship among SSM and Use-case modeling. The purpose of that work was "to identify to what extent the two techniques might be used together, in a mutually beneficial way." (Bustard et al., 1999) In this part some important tips will be mentioned from this work which will be useful in having a correct vision in structuring more useful Compound Sustainable Energy Launching framework.

1. It is concluded that SSM is a better starting point for business analysis and can be used to enhance UML.
2. Use-case analysis was developed initially for computing systems, but can also be applied to the information system within a business, or to the business itself.
3. Difference between 'actors' of SSM and Use-case diagrams:
    - In SSM actors performing activity within the system.
    - In Use-case actors are external agents that interact with a system via Use-cases.

    With this in mind the role of 'actors' in Use-case resembles to the role of 'customers' in SSM, who are external to a system and are serviced by it.

4. Use-case description contain much more detail that causes better understanding each activity while SSM is a broader analysis than Use-case modeling that more fully identifies where computing support would be beneficial.
5. Business models are easier to create in SSM. SSM leads directly to the development of coherent business models whereas Use-case modeling helps only to identify particular

functions of a business, which then need to be integrated to produce an overall description.

6. Some activities that are easily definable in SSM like monitoring and control activities are more difficult to identify through Use-cases.

3.1.2. Linking Use-case and SSM

Bustard et al. (1999) describe the Use-case, SSM relationship from two sides:

1. Use-case validates SSM model – drawing Use-case models for the same system reveals the hidden aspects and details examining the adequacy and consistency of SSM models. this validation uses the fact that each Use-case should be executable in an associated SSM model since;
   - Each interaction between a Use-case actor and the concerning system can be directly related to a particular activity in an SSM model.
   - Each Use-case can be explained in terms of the activities in the SSM model and their interactions.

One important consideration in SSM validation through Use-case is that every activity in an SSM model should be associated with at least one Use-case, because it is expected that the test will cover all relevant system behavior. "This is only possible, however, if the Use-case analysis is applied to the underlying information system of the business rather than the business itself" (Bustard et al., 1999).

2. UML with business analysis – In circumstances where the overall development goal is to implement an object-oriented computing system with UML, then an initial SSM analysis would seem to provide a good base for that work.
   - SSM root definitions identify the Use-case actors
   - Conceptual models help to identify Use-cases.

As mentioned before in the tip number five of the previous section business models are easier to create in SSM. But in some cases, there is a need to structure information system model of the principle system so that the initial SSM model will be a suitable input to compose integrated Use-case. Figure 3.2 shows a schematic Use-case and SSM relationship in which the different perspectives of system interaction are delineated.

Figure 3.2 corresponding Use-case model of a system described by SSM

The integrated diagram is named ‘interaction diagram’ here in which the concepts of ‘Entities’ ‘Stores’ and ‘Processes’ are used together with ‘SSM activities’. Bustard et al. (1999) define these concepts with an example of “Give Access to Parking Spaces”, whose SSM sub-model is shown in Figure 3.3, as:

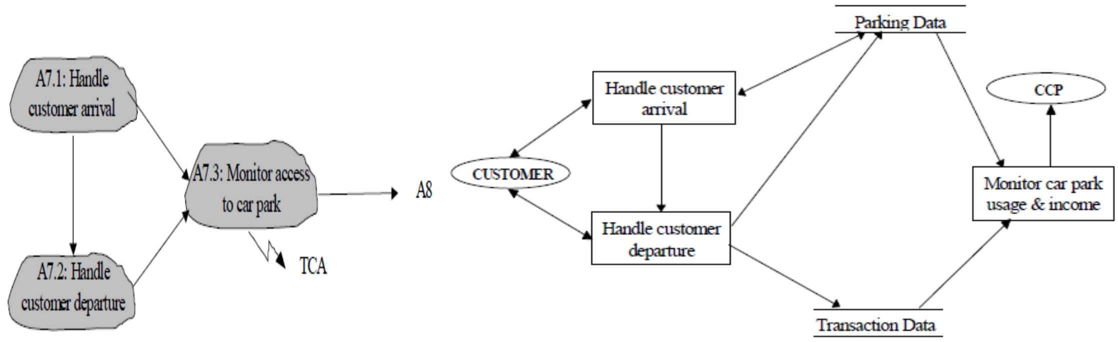


Figure 3.3 Give Access to Parking Spaces sub- model (left) and its interaction diagram (right) (Bustard et al., 1999)

- Entity: By convention, any new source or destination that is perceived to have an active role, such as the ‘customer’, is referred to an entity
- Store: any whose role is essentially passive, such as the repository for ‘parking data’, is called a store
- Processes: Entities, stores and SSM activities are known collectively as processes
- The arrows in the interaction diagram of Figure 3.3 represent the information flow.

The resulting information system is directly comparable with use-cases. Bustard and his cooperators in their work describe a flow of process to develop Use-cases from interaction diagram that is depicted in the Figure 3.4. According to this information Use-case actors and interactions of them are extracted from the interaction diagram so that the Use-cases can be developed in proceeding and the analysis of UML will be continued.

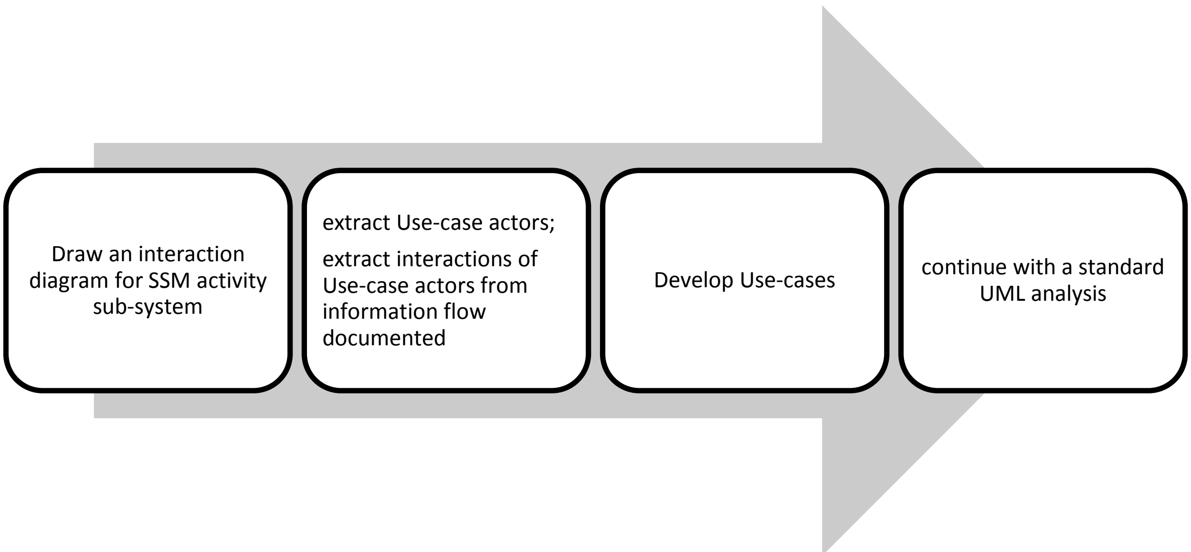


Figure 3.4 Use-case development and analysis process from interaction diagram described by Bustard et al. (1999)

Bustard et al (1999) mainly concluded in their work that:

- SSM is generally beneficial to software engineers and provide a higher level way of thinking that can help establish a well-founded business case for any computing driven business change.
- The approaches are certainly related but SSM is better suited to business analysis and Use-case modeling more appropriate when analyzing the information system within a business.
- This suggests that SSM could provide a valuable extension to UML, particularly when used in combination with interaction models.

3.2. Analytic Hierarchy Process

In day-to-day decision making processes we face some problem situations in which we have to not only choose between alternatives but also ranking them in hierarchical classifications considering their corresponding criteria. The Analytical Hierarchy Process (AHP), introduced by Thomas Saaty (1980), is a multi-criteria decision making method that reduce complex decisions in a series of pairwise decision matrixes and then capturing the results. AHP captures both subjective and objective evaluations, also providing a useful mechanism for checking the consistency of the decision maker evaluations (Calabrese, Costa, & Menichini, 2013; Saaty, 1980). Since its discovery the AHP has been applied in a variety of decision-making scenarios (Bhushan & Rai, 2004):

- Choice – selection of one alternative from a set of alternatives
- Prioritization/evaluation – determining the relative merit of a set of alternatives
- Resource allocation – finding best combination of alternatives subject to a variety of constraints
- Benchmarking – of processes or systems with other, known processes or systems
- Quality management.

Also this method has been used for decision making in different disciplinary areas. According to the study, AHP has been used in education, engineering, government, industry, management, manufacturing, finance sector and so forth. The reason why it has been so widely used is because of its simplicity, ease of use and flexibility (Shukla & Virendra, 2014). The fuzzy form of AHP also is used in ICT service industry (Calabrese et al., 2013) for decision making purposes.

3.2.1. The AHP – Step by Step

Uysal (2010) draws a flowchart in which AHP is depicted in steps shown in Figure 3.5. Hierarchy indicates a relationship between elements of one level with those of the level immediately below (Bhushan & Rai, 2004). Generally the hierarchy has at least three levels: the goal, the criteria and the alternatives (Nydick & Hill, 1992).

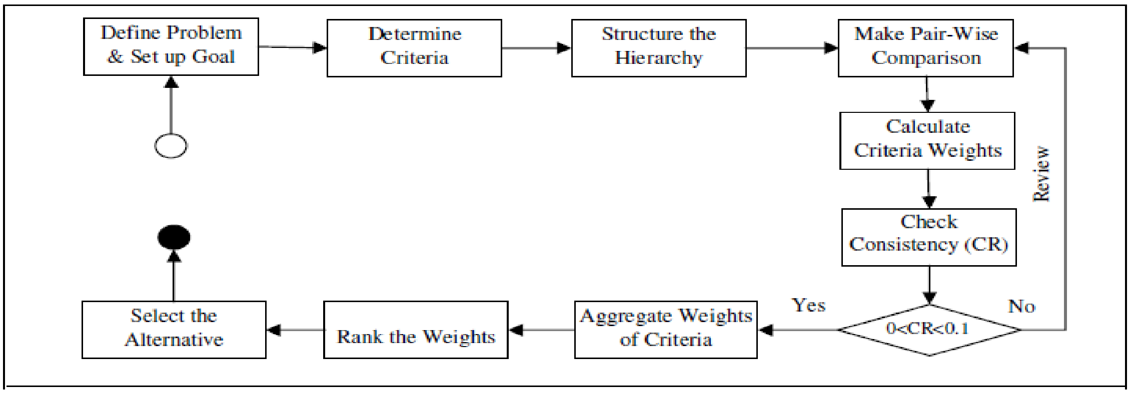


Figure 3.5 AHP flowchart (Uysal, 2010)

According to Bhushan & Rai (2004) the AHP can be explained in the following steps:

Step1 – Decomposition of the problem into a hierarchy of goal, criteria, sub-criteria and alternatives – At the root of the hierarchy is the goal or objective of the problem being studied and analyzed. The leaf nodes are the alternatives to be compared. In between these two levels are various criteria and sub-criteria. It is important to note that when comparing elements at each level a decision-maker has just to compare with respect to the contribution of the lower-level elements to the upper-level one.

Step2 – Data collection corresponding to the hierarchic structure – experts or decision makers are asked in data collection to do pairwise comparison of alternatives on a qualitative scale. Experts can rate the comparison as equal, weak importance, strong, very strong or demonstrated importance, and extremely strong or absolute importance, and then convert them into qualitative numbers as shown in Table 3.1.

Step3 – Organizing the generated pairwise comparisons of various criteria into a square matrix. The criterion in the *i*th row is better than criterion in the *j*th column if the value of element (*i*, *j*) is more than 1; otherwise the criterion in the *j*th column is better than that in the *i*th row. The (*j*, *i*) element of the matrix is the reciprocal of the (*i*, *j*) element. 1 is placed from upper corner on the left side of the matrixes to the lower corner on the right side because each alternative or criteria is equally preferred to itself.

Step4 & 5 – The Consistency Ratio evaluation – Since AHP allows for slightly non-consistency of pairwise comparisons, one important advantage of using AHP is that it can measure the degree to which a manager's judgments are consistent. In the real world, some inconsistency is acceptable, and even natural. For example, in a sporting context, if team A usually beats team B, and if team B usually beats team C, this does not imply that A usually beats team C. The point is to make sure that inconsistency remains within some reasonable limits. Of it exceeds a specific limit, some revision of judgments may be required (Nydick & Hill, 1992).

Table 3.1 Scale of Relative Importance According to Saaty (1980)

Intensity of Importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgment slightly favor one activity over another
5	Essential or strong importance	Experience and judgments strongly favor one activity over another
7	Demonstrated importance	An activity is strongly favored and its dominance demonstrated in practice
9	Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals of above nonzero	If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.	

In the AHP the pairwise comparisons in a judgment matrix are considered to be adequately consistent if the corresponding consistency ratio (CR) is less than 10% (Saaty, 1980). A higher ratio means that the decision maker is less consistent, whereas a lower one means he or she is more consistent (Uysal, 2010). Uysal (2010) in its work describes the CR formulation as following: In general, the division of the Consistency Index (CI) by the value of Random Index (RI), also known as Random Consistency Index (RCI), gives us the CR.

$$CR = \frac{CI}{RCI} \qquad (1)$$

Hence according to the equation (1) in order to calculate CR first the consistency index (CI) needs to be estimated. This is done by adding the columns in the judgment matrix and multiply the resulting vector by the vector of priorities (i.e., the approximated eigenvector) obtained earlier. This yields an approximation of the maximum eigenvalue, denoted by lambda (λ_{max}). Then, the CI value is calculated by using the formula:

$$CI = \frac{(\lambda \max - n)}{(n-1)} \qquad (2)$$

Where n is the number of items in the matrix to be compared, and the RCI is obtained from the Table 3.2 with an entry value of n.

Table 3.2 Random Consistency Index values for different numbers of items (Triantaphyllou & Mann, 1995)

n	1	2	3	4	5	6	7	8	9
RCI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Computations of the consistency ratio are somewhat more involved, but are easily performed with a spreadsheet package such as Lotus 1-2-3 or a microcomputer software package for AHP such as Expert Choice (Nydick & Hill, 1992). These days Excel also can be a suitable spreadsheet package to be used in CR calculation.

Step6: The rating of each alternative is multiplied by the weights of the sub-criteria and aggregated to get local ratings with respect to each criterion. The local ratings are then multiplied by the weights of the criteria and aggregated to get global ratings. Finally the weight values of each alternative are produced based on the judgment importance of one alternative over another, and with respect to common criterion.

3.3. MCIR Framework

Kah-Hin Chai and Catrina Yeo in their paper (2012) identify patterns of barriers to adoption of EE measures in industrial companies. They proposed a framework that categorized energy efficiency barriers based on the stage at which the barriers exist. This was a four staged framework namely: Motivation, Capability, Implementation, and Results (MCIR) and the barriers can be categorized under these stages.

There was a need for policy makers to address these barriers in a holistic manner. " whole being greater than the sum of its parts" (Rountree, 1977) due to interactions. The interconnected nature of barriers is been considered in this work whereas most prior research addressed barriers in isolation (a solution was proposed for each of the barriers without considering the relationship between the barriers). If barriers are interconnected, it is unclear whether overcoming the most significant barriers will automatically lead to better EE adoption. Due to this virtue of EE barriers there is no consensus about which barrier is the most important one. The degree of importance of the barriers is applicable only at the place and time at which the survey was conducted (Rohdin, Thollander, & Solding, 2007).

This paper also unfolds the possible interconnections between the various elements of EE such as stakeholders, policies, and barriers. This paper identifies EE policies under four major groups and argues when and what policies should be applied to better deployment of energy efficiency measures and concludes there is a need for a holistic framework development which links these policies together and takes into account the relationships between the barriers. Also this framework should take into consideration the actions of different stakeholders in the process of energy efficiency adoption. The four major policy groups are:

1. Industrial regulations and legislation programs
2. Voluntary Agreements (VAs) and fiscal measures
3. Educational and informative programs, like energy labeling, energy audits, EMS, and energy manager training and certification
4. Energy efficiency financing, that allows the borrower to repay the lender from the energy saving.

The research approach design and implementation conducted in this study begins with an extensive literature review of both academic and practitioners' publications which was continued throughout the research. Preliminary findings were used to guide data collection and analysis. Data collection in this research is through semi-structured interviews with practitioners as well as by examining the relevant documents. In addition to the list of barriers, a few interesting observations were made and worth reporting through data collection and analysis stage of research. Applying the principles of systems approach to the results attained, conclude (1) identification of interactions points, (2) integration of various stakeholders' perspectives and (3) conceptualization of a framework addresses this multidisciplinary issue.

Another aspect of the research is the companies studied in this process. In this study the unit of analysis is industrial organizations that have attempted energy efficiency improvements. In petrochemical industry energy cost is a substantial component of their operating cost; moreover several ESCOs were included as they offer interesting insights from a solution provider's perspective.

Along with barriers, some interesting observations are expressed in this study that includes:

Varying degree of commitment or motivation – in general motivation factors can be categorized in two groups of Economic Motivations and Environmental Motivations. Economic motivations are for companies where energy cost is substantial part of its operating cost (e.g. petrochemical companies) while environmental motivations are for those with a stronger sense of corporate social responsibility.

The size of organization – Larger organizations have more resources (time, staff, and financial resources), more technical ability for EE investments, wider international networks access (they are able to perform internal benchmarking with their factories in other locations, e.g. MNCs), and they are faster and more successful in adopting new technologies (Rogers Everett, 1995) while some of smaller organizations are able to overcome disadvantages by seeking ESCOs consulting services like energy monitoring and control systems installation.

Fear of disrupting production – according to plant managers and ESCOs the cost of loss in production tends to be greater than the savings projected from EE improvements.

Savings are often not visible – lack of data showing positive returns of energy efficiency.

The conducted case study is in GWM Pte Ltd Singapore, a leading global pharmaceutical based in UK. The notable success factors for EE drive in this company are:

1. Top management support to reduce the energy cost of production. According to the context, top management support has been reported as one of the critical factors of overcoming common EE barriers.
2. Division into several zones and a real time monitoring system. Facilitating EE implementation and responsible managers for energy initiatives and performance for each zone are benefits of division. Also real time monitoring system helps actual energy saving verification as a result of improvements.
3. A five percent annual energy saving target. This cause energy consumption to be one of top five key performance indicators of the plant (e.g. Energy consumption, safety, quality indicators…) also served to overcome resistance to change and in fact fear of risk to production.

Qualitative data collection results are integrated with following remarks and thinking in framework development process:

- The industrial sector as a heterogeneous “system”. This means in large number of organizations there is variation in energy intensiveness degree, corporate social responsibility, employee number, and socio-technical networks extent.
- Technical, organizational and behavioral barriers interplay.
- Interests and objectives of stakeholders (organizations and governments have both short-term economic concerns and long-term sustainability concerns).
- EE adoption as a change process (changing existing practices, also adopting new and more energy efficient processes). Therefore, from an organizational perspective, energy efficiency improvements are innovations which involve changes that have to be managed properly (Chai & Yeo, 2012).

The proposed framework results in two major applications: (1) offers a way to understand the roles and responsibilities of major stakeholders such as government and energy service companies (ESCOs); and (2) allows the assessment and identification of weak links in EE policies.

3.3.1. How to use MCIR framework?

Questions in each stage of the framework of the Figure 3.6 capture factors affecting EE adoption, moreover reflects the interests and objectives of stakeholders. Due to application of this framework in the proposed compound framework the stages are identified here according to Chai and Yeo (2012).

Stage1. Motivation – The primary concerns at this stage are the organizations’ interests in pursuing EE, More over awareness of EE opportunities is considered at this stage.

Stage2. Capability – Organizations are concerned with their capability to pursue and implement EE competently. They will be interested in where and how they can assess the capabilities needed.

Stage3. Implementation – The concern in this stage is whether capabilities acquired in the previous stage can result in successful EE projects.

Stage4. Results - It refers to the outcomes of implementing energy efficiency projects. Top management will now ask if the efforts to implement energy efficiency were worthwhile. Given that what you can measure you can manage, it is necessary to be able to quantitatively demonstrate the returns on such efforts.

Feedback – Success breeds success with positive feedbacks. The outcome of the “Results” stage is the feedback to the “Motivation” stage. Positive feedback needs to be emphasized and is effective in motivating top management to further invest in EE.

In the remaining context of this section MCIR will be explained in its three major purposes;

1. How to engage MCIR to analyze barriers to EE and map them on this framework
2. How to analyze the stakeholders' roles in EE adoption
3. How the framework can be used as a theoretical guiding framework for energy efficiency policies.

3.3.1.1. Mapping identified barriers into MCIR framework

This framework identifies chokepoints of EE, by considering the interactions of barriers and the possible sequence in which they may occur, as a helping tool. Chai and Yeo (2012) in their work, group common barriers under MCIR classification first, and then use a case study to demonstrate the functioning of this aspect. In the following the specifications of different groups of barriers are discussed, according to that context, and then the classification is shown on Figure 3.6.

1. Motivation barriers: These barriers can be broadly classified into economic sense ("brain") and environmental sense ("heart") barriers and are those barriers which lower management's interest in pursuing energy efficiency. These barriers can be:
   - A lack of financial incentives (e.g. if energy expenses are only a small fraction of overall operating cost, lack of capital to pursue capital-intensive technology)
   - Misplaced incentives (Brown, 2001)
   - A lack of awareness of energy efficiency opportunities.
2. Capability barriers: Broadly classified into technical and financial barriers, as shown in Figure 3.6. Typical barriers at this stage are:
   - A lack of information on energy efficiency technologies
   - A lack of trained manpower
   - A lack of financial resources.
3. Implementation barriers: Are barriers that inhibit the implementation of the energy efficiency projects. Common ''Implementation'' barriers include:
   - Resistance to change
   - Short windows of opportunity for engineering changes given that many manufacturing organizations operate on a 24/7 ("24 hours a day, 7 days a week") basis and there is a fear of disrupting existing production processes.
4. Results stage barriers: These barriers are widely reported but often articulated in different ways. Essentially, the biggest barrier is the lack of positive results from energy efficiency investments.

   To the organizations, results can be interpreted as economic and financial gains. Companies expressed that there are often little or insignificant energy savings from energy efficiency efforts, failing to recognize the fact that energy costs often do not constitute a large portion of total operating costs, and hence energy savings through energy efficiency adoption may be easily offset by other changes such as increased manpower and production changes.

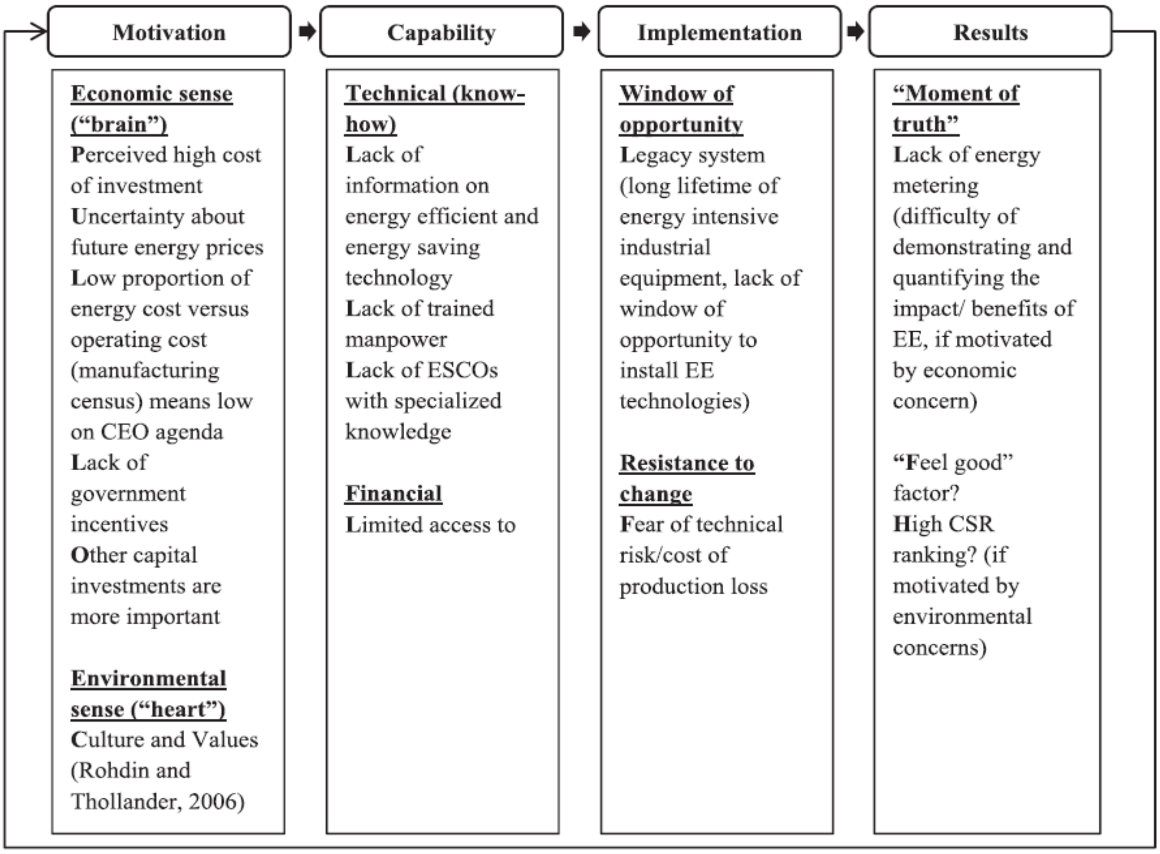


Figure 3.6 mapping barriers into the MCIR framework (Chai & Yeo, 2012)

3.3.1.2. MCIR framework to understand the stakeholders' role in EE adoption

Chai and Yeo (2012) argue that the MCIR framework can be applied to understand the roles of the major stakeholders in improving energy efficiency. The stakeholders in this study are identified as those who have a more direct influence on EE, and taking into consideration of these roles give a big picture that enable seeing complex dynamics between the various stakeholders in driving energy efficiency. Stakeholders help to strengthen the link between stages. In this part the major stakeholders are introduced according to Chai and Yeo that their roles are classified by Table 3.3.

Government: Due to the nature of energy efficiency collection of individual projects can save a substantial amount of energy for a large corporation or nation. More over energy efficiency is always a powerful tool in combatting climate change and achieving energy security, especially in countries with no or low energy resources. Therefore, governments should be major stakeholders in realizing the potential of energy efficiency in the industrial sector. Voluntary agreements are examples of motivation for the industrial sector to pursue energy efficiency as they can provide win–win situations because they are effective without effecting industry competitiveness. The government also can provide capabilities for the industrial sector such as the provision of energy manager training and financial incentives. They can also help to overcome ''Implementation'' and ''Results'' barriers through target setting and establishing a standard protocol for energy reporting respectively.

Industrial organizations: They are motivated to reduce costs and display corporate social responsibility. Top management can induce an energy efficiency culture to promote energy efficiency adoption in their organization. Seeking help from technical consultants and appointing energy managers are ways to reduce ''Capability'' barriers in organizations. The formation of cross-functional teams can help overcoming implementation barriers. For the stage of results industrial organizations should collect relevant and accurate data on energy savings and energy efficiency improvements so that sustained improvement will be achieved and also such data can be used for benchmarking purposes.

ESCOs: They mostly help to reduce capability barriers, and in particular the technical capability barriers by performing energy audits and recommending EE improvement plans. Experienced ESCOs also provide a source of information for industry best practices and benchmarks.

Customers: Their demand will direct the companies' market and development policies. As the number of "green" customers increase, motivation for EE is expected to increase.

3.3.1.3. Using MCIR to access policy effectiveness

Although organizations use MCIR framework in energy efficient technologies adoption, policymakers can also use it to analyze energy efficiency shortfalls in the industrial sector of their countries. Depending on the prevalence of the type of barriers, the country could be facing ‘‘Motivational’’, ‘‘Capabilities’’, ‘‘Implementation’’ or ‘‘Results’’ barriers, or it could also be a combination of two or more categories. Such an analysis gives clues to the weakest link in the framework, which then aids governments to determine the type of policies to introduce (Chai & Yeo, 2012). Figure 3.7 illustrates how the MCIR framework may help policy makers. The vertical axis shows the number of organizations involved in each stage of the adoption. It is implied that the higher the level of the stage, the greater the number of organizations are involved, thus the fewer the barriers faced in that stage and higher adoption of energy efficient technologies and practices (Chai & Yeo, 2012).

Table 3.3 The roles of stakeholders (Chai & Yeo, 2012)

Motivation	Capability	Implementation	Results
Government			
- Voluntary agreements - Education and awareness - Regulations and legislations	- Financial grants and incentives - Provision of energy manager training	- Target setting - Benchmarking - Provision of network platforms - R&D of energy efficient technologies	- Standard reporting protocol to account for economic benefits of EE improvements
Industrial organizations			
- Corporate Social Responsibility (CSR) - meeting employees' expectations	- Energy audits - Engage consultancy	- Overcome resistance to change/ alignment to values - Target setting - ISO 50000 - Outsourcing - R&D of energy efficient technologies	- Energy data collection and monitoring
ESCOs			
	- Energy audits and improvement Recommendations - Sharing of best practices	- Follow up sessions - ISO 50000 - Benchmarking - Lean and Six Sigma	- Techniques or tools to measure and quantify benefits of EE
Customers			
- Demand for ‘‘green’’ product (lower carbon footprint)			

To strengthen the link from one stage to another, the chokepoints should be eliminated one by one referring Table 3.3 presented earlier. For example, according to the same reference, in the situation depicted by Figure 3.7 a large number of organizations are motivated to pursue energy efficiency, as indicated by the high vertical in the ‘‘Motivation’’ column. However, these organizations lack technical capabilities among these organizations, as shown by the partially shaded column. To strengthen the link from one stage to another, the government should first try to raise the capabilities of the organizations for energy efficiency, such as by promoting ESCOs or providing energy efficiency and management training. If ‘‘Implementation’’ barriers exist after building capabilities, the government can enforce implementation energy efficiency actions.

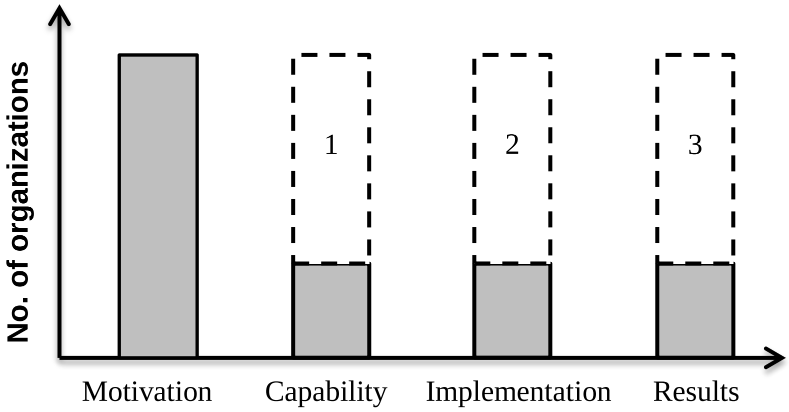


Figure 3.7 Application of MCIR framework to help policy makers (Chai & Yeo, 2012)

Chapter 4. Compound Sustainable Energy Launching (CSEL) Framework

Some works which already have been done and frameworks already have been made in developing energy sustainability are explored in order to get an idea about a compound holistic model which becomes effective in launching sustainable energy measurements while keeping simplicity. This model is named Compound Sustainable Energy Launching (CSEL) Framework in this work. Soft systems methodology developed and explained by Checkland is used fundamentally for this framework. This model consists of three major subsystems that interact with each other as driving motor of the holistic model.

The first major subsystem assigns the interest inside the industrial group or organization. In the construction of this sub-system the model prepared by Neves (2002) to rethink the analysis of energy efficiency Initiatives is recognized suitable. Although this work was done in macro level for industrial sector of the whole country and rather we wanted to assess interest in a lower level, inside one complex of the whole industry sector, but conversion of some activities and sub-activities of the prepared model make it suitable to use in lower level. Also AHP model, which was developed for the first time by Saaty in the 1970s, is used in order to get and convert the result of assessment in numeral percentage form.

The second major subsystem basically has its roots on the use of SSM to address one of the most important factors in sustainable energy development, namely gaps. MCIR framework already developed by Chai and Yeo (2012) from national university of Singapore is an admiring framework that addresses both barriers and gaps on the way of sustainable energy development.

The third major subsystem of the framework is been developed by the aim of triggering one of the most important factors of energy efficiency development; the budget assignment, by considering the fact that this assignment should be effective in terms of gaining as much energy efficiency results as possible from the lowest amount of money assigned. The second use of AHP model in CSEL framework is in this major sub-system. Figure 4.1 shows a schematic objective of the third model in which is to balance improvement of sustainability indicators with their cost for capital investment.

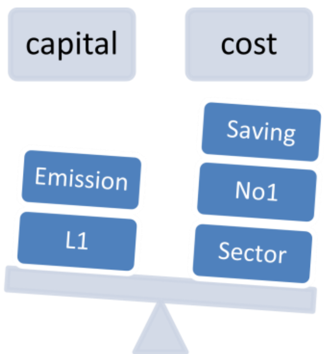


Figure 4.1 cost effectiveness of CSEL decision making framework

Finally this major sub-system is needed to be expressed via a system language to depict the information transfer inside the model. This evolves the question whether UML can be helpful or not and how else it can be used. The Use-case model is used to depict the information flow concluding the results in the third model. Also the work done by Bustard et al. (1999) gives more ideas about the application of UML in compound model building process that already has been discussed in section 1.6.

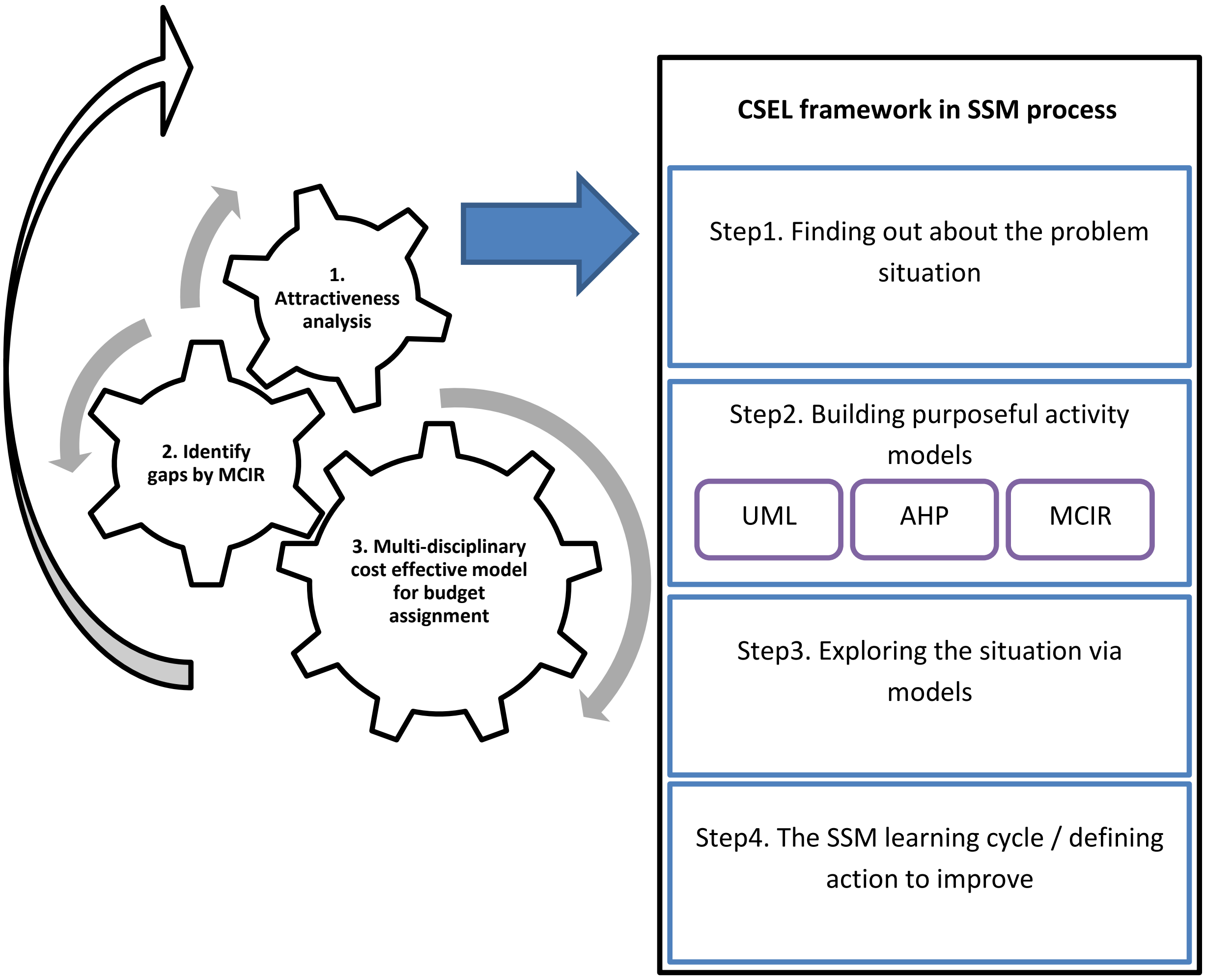


Figure 4.2 Compound Sustainable Energy Launching Framework development based on three major objectives

Figure 4.2 in the left side shows the three major objectives of CSEL framework development. This is itself subject of a study using SSM (p) in order to assemble the most suitable and effective framework for this purpose in different locations, sectors and also for different industry sizes. It is expected that this work as a prototype help decision makers to develop such models in their own environment or find it useful in surfing the space among Sense-making until Action-to-improve in favor of sustainable world. Figure 4.2 in the right side shows the use of SSM (p) in the framework development.

4.1. Sub-system 1&2, purpose and base

The existence philosophy of these sub-systems is the need for continuously questioning the industrial complex for the amount of interest in order to become sustainable from the energy viewpoint. The result of sub-system one is required to be in quantitative form of percentages, so that the percentage of the interest could be negotiated as being a multiplier of the whole periodic budget of the company. The fact is that this is a dynamic model and we may observe also synergy in favor of sustainable energy. This means, the primary interest rate causes commencement of a cycle which periodically assesses the interest on sustainable energy initiatives and on the other principal objectives of the company in their meetings and planning, and causes action-to-improve which happens in other subsystems of the holistic model. In some cases the results may become inspiring from right beginning cycles so that synergy is expected by provoking the motivation, especially among senior management.

4.1.1. Macro-level basic model: SSM to Rethink the Analysis of Energy Efficiency Initiatives

As mentioned before for the sub-system one a model prepared by Neves and his teammates (2002) in macro level is used. This model is prepared with the aim of providing public and private initiative promoters with a structured support for a more informal decision. The root definition in this work is: “System which aims at evaluating the interest of promoting each initiative to foster the efficiency of energy end-uses considering the direct advantages and disadvantages to the promoter, as to other involved entities”.

Clean Energy Ministerial in its website, (“Initiatives | Clean Energy Ministerial,” 2014), speaks about its initiatives for energy as: “ The initiatives focus on empowering energy decision makers with the information and tools they need to improve the policy environment for clean energy around the world. The initiatives’ low-cost, high-impact work also facilitates international coordination that amplifies each government’s clean energy deployment efforts”.

According to this work, SSM is used because of a need to a complete re-statement of the problem, so that all actors and issues are clearly defined. The resulted rich picture of the problem situation is shown in Figure 2.3. In this work six agents are identified with a potential interest in a system to analyze E.E. initiatives. These six agents are:

1. An Energy agency: to manage public funds.
2. The energy market regulator: can be mandated to foster energy efficiency not only economically but also from the energy view point. This agent needs to evaluate regulated companies for their proposed initiatives.
3. The government: spending tax money for legislative measures.
4. Energy companies (Electric energy in this study): for different roles of generation, transmission, distribution, and retail companies.
5. The Energy Service Companies (ESCOs): EE is as a business for these companies, they propose initiatives based on pure business analysis and cooperate with other entities which may need in some cases a system to demonstrate the interest.

6. End-use equipment manufacturers/ dealers: they bring efficiency to the market so can be forced to cope with efficiency standards or labeling schemes by the government, or they can be solicited to participate in specific initiatives. They can also apply for financing in order to accelerate the introduction of new technologies in the market.

All these six agents need to consider a position regarding not only their own initiatives, but also the initiatives of others that may have an impact on their "life". The rich-picture shows other actors affected by or influencing decisions, namely the affected energy consumers, environmental pressure groups and the society as a whole, but none of these entities can be seen as a user of a system of analysis, except indirectly through one of the other entities (Neves et al., 2002).

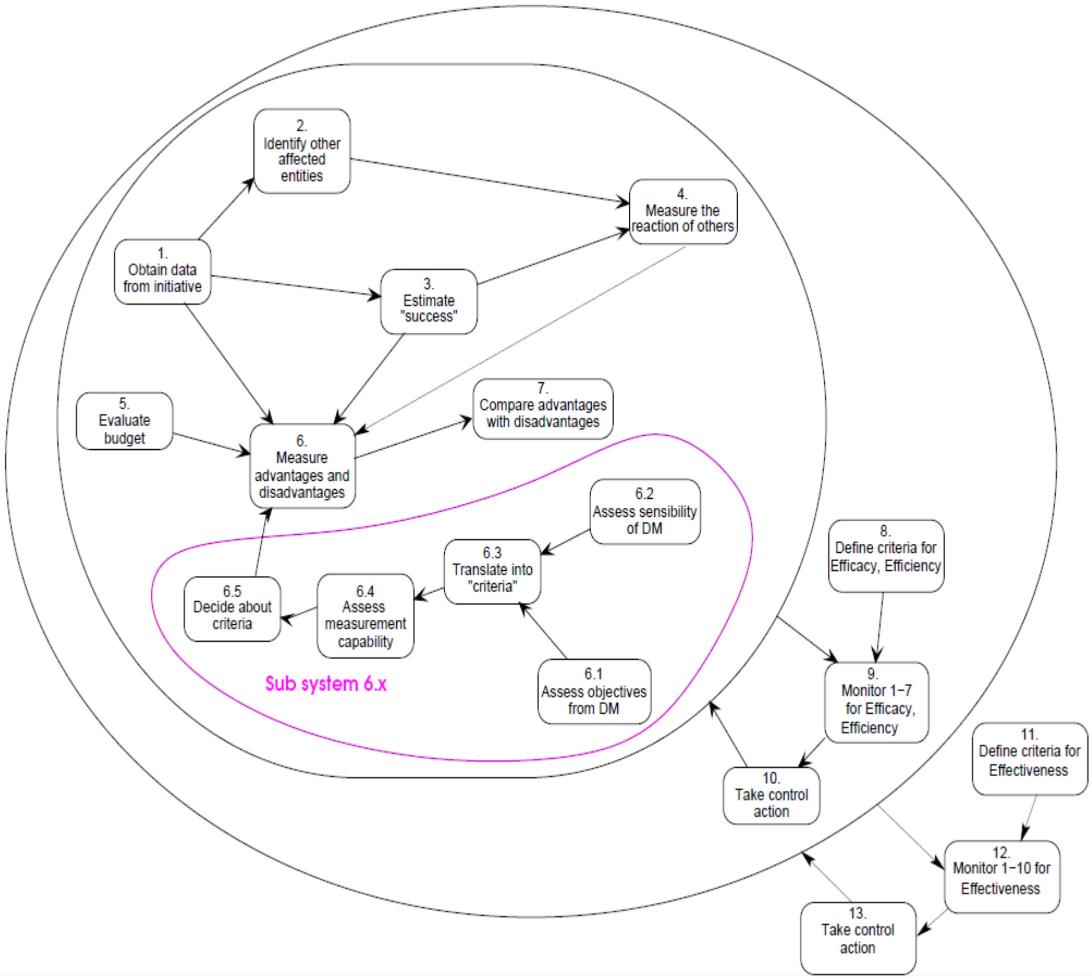


Figure 4.3 prepared model in macro level (Neves et al., 2002)

4.2. SSM to structure the CSEL framework

About with Compound Sustainable Energy Launching framework (CSEL) soft systems methodology is applied using the four main activities described in section 2.3 as found in Checkland (2010) for two purposes:

1. Structuring the most suitable model for sustainable energy deployment
2. Implementing the model in order to take optimum changes iteratively in each cycle.

As mentioned before this framework is going to be structured to help deployment of the energy sustainability in industry section of what that is illustrated in Figure 1.1 about sustainability levels. Three different companies represent the industrial sector in this study and will be introduced in the sub-chapter 4.2.2.1.

4.2.1. Finding out about the problem situation

In addressing the Iranian industry sector for sustainable energy, cheap energy prices stipulated by Iranian government as part of its policy agenda to protect and serve the poor constitutes an also indirect subsidy for energy carriers have to be considered. Efforts over the past decade to improve pricing policy via Price Reform Policies have only slightly improved prices in real terms and have not succeeded in DR. These subsidized low prices result in the irrational, over-consumption of energy which is reflected in the high energy- intensity indicator compared to other countries and a sub-optimal energy mix (Sabetghadam, 2006). Although it was expected that Resistance Economy policy act as a strong driver in favor of Energy Sustainability but yet it seem that mostly industries are reluctant, or at least not enthusiastic in this subject and further exclusive study and work is required to be done. SSM can systematize the learning and action to improve process for sustainable energy deployment and in this part SSM process is developed by rich picture structuring, analysis one, two and three as mentioned in sub-chapter 2.3.

4.2.1.1. Making Rich Picture

The resulting rich picture, which is shown in Figure 4.4, illustrates some main entities that are effective directly or indirectly in sustainable energy measures deployment in the factory level of the industrial sector.

Although some entities namely: Government and Authority, Suppliers, ESCO, and Customers are outsiders of the factory level, they are shown in the rich picture since they have direct effects or close relationships with the system under study that cannot be omitted when studying the factory level system.

The Government & Authority here represents a group of entities like Energy Ministry, Energy market regulator, Energy Agency, Energy commission of parliament and other public entities that are in charge of Energy Demand Reduction (EDR) and deployment of sustainable energy measures under Resistance Economy strategies and other planned energy strategies of long-term or periodical development plan in Iran. These entities potentially foster sustainable energy measures through their initiatives or through financing third parties, attribution of tariff mechanisms, legislative measures for motivating the market and changing market behavior to make Energy Sustainability a generalized request with directing financial support from tax income or National Saving Account to this area, considering all social and political aspects.

Utilities here represent the Energy companies, which are mostly governmental organizations, and generation of final energy by the companies using electricity generators or RETs and also water supplies whether by government or independently, so that the government is in charge of production, transmission, distribution and retailing. In Iran 97.4% of electricity generation capacity belongs to the Ministry of Energy (Sabetghadam, 2006). Although in some places renewables also may be used, Iran is a suitable place for catching the energy from sun and wind. Also hydro is being applied in some locations in electricity production by transforming hydraulic energy of falling water out of dams, which again are governmental utility supplies. More over water supplies also are done by the government in Iran. Power Ministry is in charge of water and electric supplies and Oil Ministry is in charge of fossil fuel supplies. The policies in this area according to Sabetghadam (2006) are expanding electricity capacity, natural gas production and consumption, renewable energy (RE), and also price reform policies/programs.

Energy Service Companies (ESCOs) are expanded these years and are organizing themselves for complying needs of energy efficiency and sustainable energy measures. These companies have an important role in correctly deployment of energy sustainability since they undertake a vast spectrum of activities from consultancy to training. For this purpose it is very important that these companies become as much organized as possible with adequate information, experience and skilled human resource.

Suppliers and Raw Material represent that part of system that is in charge of procurement and supplying the company level. This entity potentially helps sustainable energy deployment by asking end-use equipment manufacturers for efficient and labeled equipment and by considering energy consumption considerations in raw material selection.

Equipment and Machines section in the company closely relates to suppliers and similarly helps sustainable energy deployment by requesting for energy efficient and energy labeled equipment. Also we cannot relinquish the role of maintenance in energy efficiency.

Board of Directors including supreme management is the most efficient part in launching sustainable energy measures. When supreme management intend to deploy EE and sustainability measures, especially in Iranian industrial environment, lots of barriers along are eliminated and budget assignment can be happen easily and effectively.

Management Systems entity is responsible for energy management systems deployment inside the company. It is important to notice that the effectiveness of management systems deployment depends on the whole company attitude for being sustainable and launching these systems does not necessarily leads to efficient sustainability in energy section.

Customers' role also is very important because companies these days are becoming aware that they have to take special attention on value proposition for customers. So that the customers can request products with the production processes in which energy sustainability is applied. This can through requesting products with energy management systems labeling like ISO 50001.

The roles of other sections that are shown in the rich picture are dependent to the sections that mentioned above. To be more specific when an energy management system deployment is adopted in factory level, then it is needed for adjustment of those who are responsible for energy management inside the company. Education plays important role in motivating and implementing energy sustainability measures. Head of departments are the second stage after supreme management in this study that have important role in EE and sustainability deployment when after these stages are factory workers that can help by applying what they educated and ordered for, also by giving useful feedbacks and recommendations in this aspect. If we consider EE and sustainability similar to a big change like innovation then the importance of the R&D section will be revealed in which new energy efficient technologies and methodologies are studies and the possibility of utilizing renewable energy technologies are recommended to the decision makers and board of directors.

Some of relations among these entities are as following:

- Government & Authority helps ESCOs by regulations and monetary supplies and defines the rules for energy intensive companies which management systems inside the company have to notice them. Moreover board of directors has concerns about the resistance economy of government and their own priorities that they have to be well informed and accredited.
- Energy service companies primarily have close relationships with board of directors, and government and authority. The supports and regulations come from the government and authority which enables the ESCO to have contracts with board of directors, so that ESCO help the company in different aspects like educations and training and EMS deployment. Also ESCO can train, certify and recommend certified responsible energy managers inside the companies. The R&D section can join these companies so that they can have information interchange. Also it is important for the part of utility that is supplied from the energy companies to have relationships with ESCOs, since they are companies themselves and have to prevent the energy wasting in the production and distribution process. Moreover ESCOs can give precious information for utilizing RETs inside the companies.
- The other relationship is the production process in which board of directors are connected to head of departments that themselves are working with factory workers and technicians.
- Suppliers and Raw material, Equipment and machines, and utilities are potentially able to cope with efficiency standards and energy intensity reduction in factory level. They can communicate for eliminating barriers like asymmetric information barrier, lack of information and principle-agent problems.

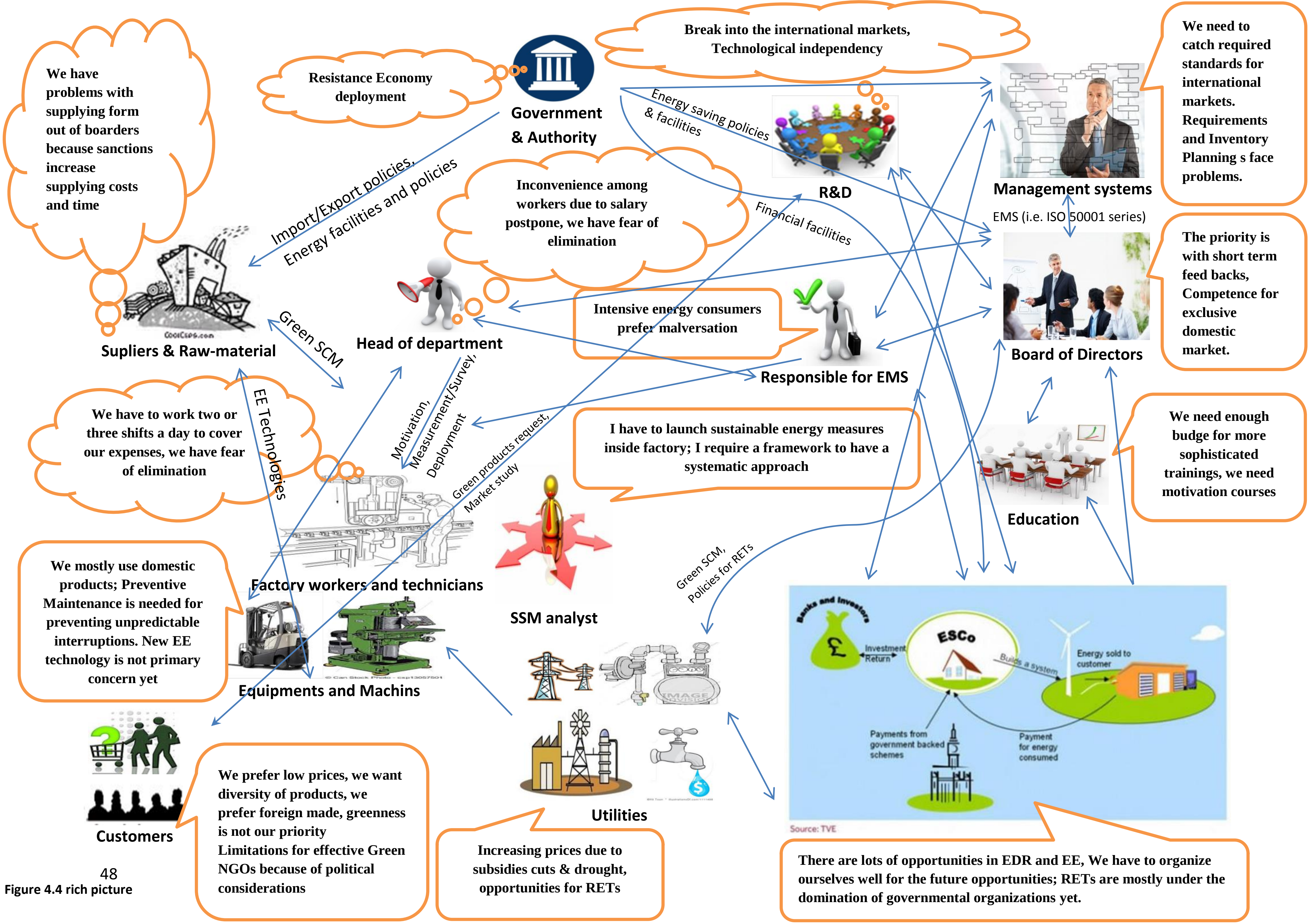


Figure 4.4 rich picture

4.2.1.2. Analysis One, Two and Three

Analysis One, The intervention itself:

As mentioned before this essay aims at preparing a compound framework to launch sustainable energy in Iranian industry section. First of all it has to be mentioned that this is a university work in master level that the practitioner which is the author of this essay prepares for his supervisor. The Iranian companies visited and the consultants interviewed are the other side of the study that can be potentially in the clients' position. Also this project can be attractive for Iranian government with the aim of Resistance Economy deployment. This framework is developed because efficient launching methods were being explored for effectively launching energy sustainability policies in Iranian companies, so that the author himself can also be a client for this study. More over this study can be attractive for other governments that are similarly trying to deploy sustainability in their countries and want to overcome barriers. With this in mind the Checkland's three key roles for this case are defined as:

1. Client: Iranian government and similar foreign governments, ESCOs, industrial sector
2. Practitioner: A systems analyzer/ ESCO
3. Owner: Government/ ESCO.

Finally it has to be mentioned that in this condition the practitioner was aimed to develop a model to cope with real problem situation, so that himself can be also the owner.

Analysis Two, Social and Analysis Three, Political

In order to get enough data and information required for analysis two long time interventions and study is required to get the general roles, norms and values in Iranian industry section. Also about with analysis three enough time with engagement is required to get the commodities of power, but the most time consuming part is finding answer to the question about the processes by which these commodities are obtained, used, protected, defended, passed on, relinquished, etc.

In the understudy factory, the experience and being old in that company was very important, even if the experienced person was not undertaking the position in his/her own educational field. I noticed that the skills and knowledge are not as much important than resistance in turbulences like wage delays and job security. The out comer in this system mostly is counted as a potential danger because the teamwork is just for survival and helping each other to stay in the positions, so that no body trusts a system analyst. Even superior management feels that there are more important aspects of job than analyzing the system, namely connections with the competitors and supplying companies.

4.2.2. Building Purposeful Activity Model

4.2.2.1. Root Definitions, CATWOE and Multi-level Thinking

The Idea for developing a model for sustainable energy deployment came when I decided to contribute in energy management system deployment in an Iranian company, named Iranians' EMS near the capital of Iran in Tehran. I noticed that there are strong barriers whether culturally or financial-organizational. More information was gained from interviews published by public TV channel of IRI and also face-to-face talking with my friends and active consultants in Iranian energy sector that results in definition of T, CATWOE and PQR of this study.

Table 4.1 Information based on observation, communication or interview

Case	Observation
Automobile key & switch manufacturer	**T**he raw material was coming from China but there were delays due to problems in delivery all because of political situations. **S**ome of employees were working there with months of delay in wages payment so they had to work in other places to compensate their expenses. Yet they were hopeful because they thought this is temporary condition and they will get their salary soon. **T**he factory did not have enough money to invest on suitable management system. **I**n this condition the competition among the employees themselves and among groups of employees and supreme management was very fierce. **T**he government has to not only push these industries but also implement its resisting economy and manage the consumptions. **B**eing an old comer in this company was precious science they have had very hard period with no salary and no production. **N**obody says no for new systems and ideas but there are no capability and protect in action. **T**here is lack of knowledge about advantages and effects of an energy management system. **E**nergy is accounted for a very little proportion of the expenses inside the factory. **T**here is resistance in accepting out comers especially those with foreign backgrounds and also those who are able to clarify the statistics and system processes.
Petrochemical Industry	**E**nergy accounts for a considerable amount of expenses. **T**here are a group of people in charge of environmental standard and ISO14000 series. **N**o serious action has done yet for energy demand reduction and control. **T**he main concern is contractors who did not win the contract fairly and are not responsible enough. **T**he company manager shows open mind for any study and analysis inside that industrial zone. **T**he most important barrier is indicated to be malversation (misconduct in public office) and corruption in organizations. **T**his group of industry needs some motivation and regulatory obligations. **T**here is a requirement to detect the barriers and gaps more precisely.
ESCO	**A**ccording to his statements some sustainable energy measures require long term return of investment acceptance while the investors these days are looking for short term effects and return of capital. This is an important consideration in our model building process that illustrates the requirement for a model to motivate the investors periodically by short term paybacks and make them interested in long term fundamental investments on sustainable energy. **H**e believes that graduate analysts and experts from foreign universities have better chances in being accepted in academic and private sectors of society. Yet staying inside and depending on the current systems for sustainable energy deployment is not wise. **T**here are huge amount of investors in the country that are looking for reliable investment and this is an opportunity to draw the lines for production with sustainable energy considerations.

In “Iranians’ EMS” company that essentially assembles automobile starter switches, door keys and locks, the sanctions cause lots of problems. More over the factory is on its beginning steps of mass production. I was fortunate to attend the directors meeting inside the company. The other interview was conducted from a manager of a petrochemical industry, and the third case is conversation based information from an architect, Energy Management professor and consultant inside the country that is represented with ESCO in Table 4.1 along with information from other companies.

Checkland recommends that the starting point becomes T and W definition of CATWOE. First of all the required information for identifying the W is taken form the site visiting, interview and conversation mentioned above.

1. Although the country is in economic crisis, energy sustainability is required.
2. Resistance economy, a strategy developed by the government, requires energy sustainability and EDR.
3. Investors have to be motivated to move from short payback period expectation to long term paybacks in EE and energy sustainability investments.
4. We need a framework that covers all industry from different sizes and different conditions.

The concluding W will be “to facilitate sustainable energy launching in all economic conditions of Iranian industry”. According to the conversations and site visiting the “T” of CATWOE can be defined. There is a need for a model or a framework to capture the interest, diagnose the system for gaps and barriers and finally to ignite the sustainable energy deployment process in the company in cyclical periods that cause synergies in energy sustainability.

The possible PQR transformation that is suggested for this study can be as following:

P. Building and implementation of a framework for sustainable energy launching ;

Q. By a review on decision making methods, works already done in similar conditions, and using SSM method to assess, develop and implement the framework in periodical manners;

R. Facilitate launching sustainable energy measures in Iranian industry sector.

This can be expressed in an Input/Transformation/Output form:

- Input: need for a sustainable energy launching framework to take interest, diagnose the system, and assign money.
- Transformation: Building a framework to take stakeholders’ interest, periodically assess the barriers and gaps of energy sustainability and assign desired budget effectively in favor of energy sustainability.
- Output: A CSEL framework that takes the interests of the stakeholders, periodically assesses the barriers and gaps among energy sustainability, and helps decision makers in efficient budget assignment.

To be more specific we can tabulate the CATWOE as following:

Customer – The system analyzer, ESCOs, the beneficiaries (the companies, governments, equipment manufacturers, environmentalists…Etc.) and victims (Energy companies?, Governments, equipment manufacturers…Etc.).

Actors – The DM, i.e. the promoter of energy system inside the company, the responsible energy manager for EMS deployment in companies, outsourced entity for EMSs.

Transformation – Building and implementation of a framework for sustainable energy launching.

Worldview – Facilitate sustainable energy launching in all economic conditions of Iranian industry.

Owner – The government, ESCOs.

Environment – Industries with different sizes, and interests.

Root Definition: The RD according to defined CATWOE will be:

"To Build and then implement a framework to facilitate launching energy sustainability with an analyst or group of specialists using SSM method, including industries with different sizes and different interest rates on sustainability initiatives".

4.2.2.2. Model Building for CSEL framework

As T, RD (PQR), and CATWOE are defined in the previous section the model building starts with defining the criteria for the so called 3 Es, according to the RD:

Efficacy: The system identifies correctly a sustainable energy launching framework that takes interests on sustainable energy initiatives, analyzes the barriers and gap, and recommends efficient capital investment according to the interest rate.

Efficiency: The system works with the minimum resources.

Effectiveness: The model motivates corporations for sustainable energy initiatives by periodically taking their interest for sustainable energy initiatives, assessment of barriers for elimination and effectively assigning the budget according to their interest.

The resulting conceptual model of the system is shown in Figure 4.5 together with a sub-system found to be necessary during the modeling phase.

The whole process of the model is being explained with a numerical example just for illustrating how this model works. As mentioned above this model, with utilizing SSM, has to be revised periodically and implemented with adequate time assignment and sufficient group members.

The AHP model applied for activity 5 requires the determination of people who will be surveyed, to get the interest rate for energy sustainability, and then classifying them in three levels of hierarchy. Also the criteria have to be identified under which the three alternatives of

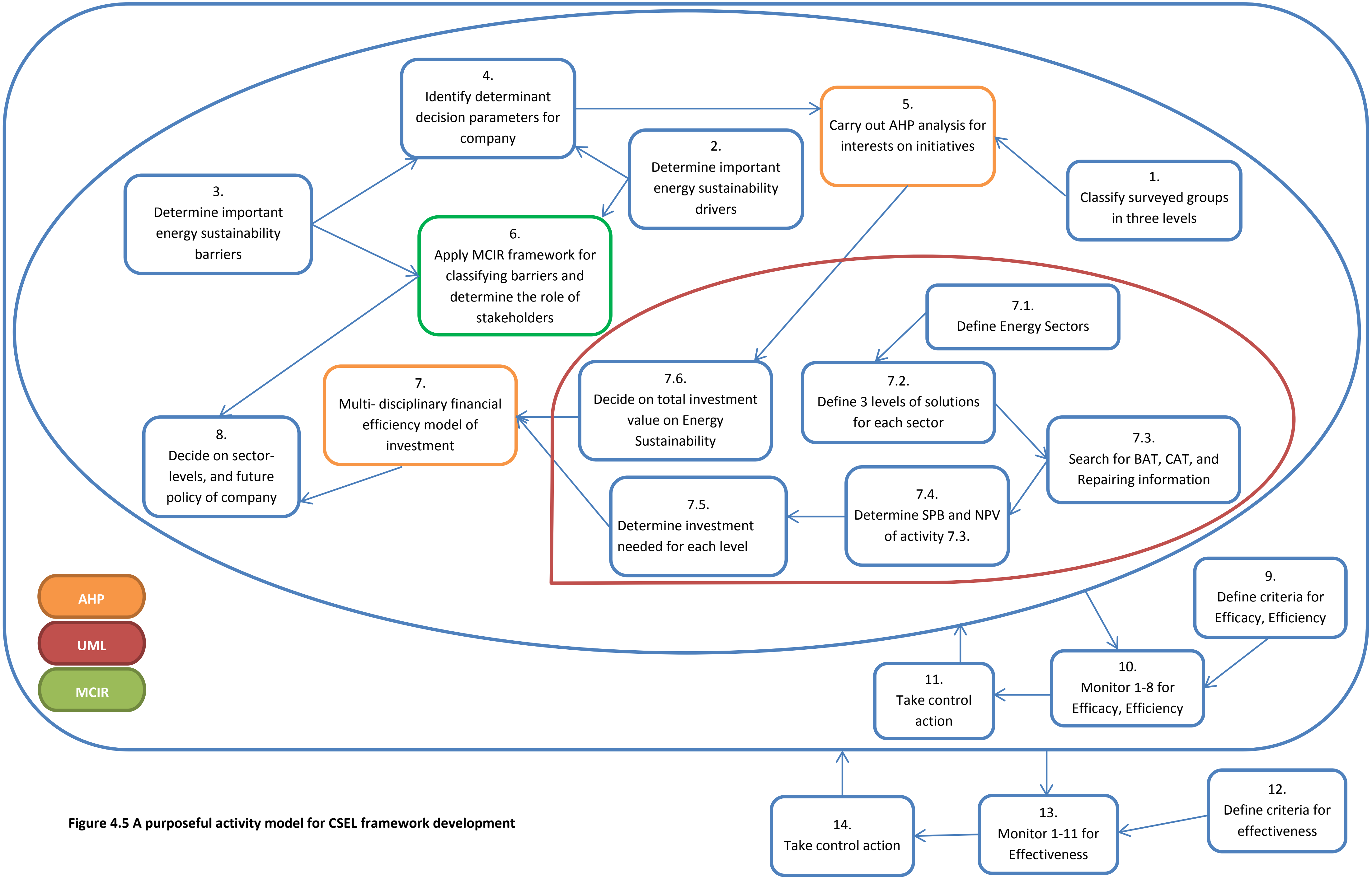


Figure 4.5 A purposeful activity model for CSEL framework development

Staying in current position, Moderate change towards sustainable energy (EE), and Fundamental change (EE & RETs) will be assessed to take the interest rate for each of these alternatives.

Activity four takes information and results of the survey which should be done for determining important energy sustainability drivers from activity two and important energy sustainability barriers from activity three. Then it decides on the determinant decision parameters which can be used as Criteria in AHP model.

Our prototype industry in this study is a well-equipped average sized Iranian petrochemical factory in a condition that the government intends to implement the Resistance Economy policy in the country. With this in mind in our prototype industry, people under the survey are classified into three levels of:

Level 1. The board of directors
Level 2. The head of departments
Level 3. The factory workers, engineers and technicians.

In the process of determining the key barriers of industrial companies, the data collection detail is shown in Table 4.2 and the respected key barriers faced by industrial organizations under study are shown in Table 4.3, which uses the key barriers of the original MCIR development study (Chai & Yeo, 2012). Malversation and corruption is added to the list of barriers because it can bring all sustainable energy measures and legislations to the standstill. Also lack of attitude for energy investments with long-term payback is concluded to be very important. Although it can be the result of other barriers like lack of capital or information, when in fact the barriers are dynamically interrelated to each other, it is indicated separately due to its importance nevertheless. Drivers of energy sustainability can eliminate barriers and foster the implementation of measures to have acceptable saving and sustainability results.

Table 4.2 detail of data collection from industrial sector in 2014

Company	Industry/notes	Source(s)	Status on Sustainability
A	Assembling automobile starters, locks and switches	. Site visit . Attend decision making meeting . Employees	Energy is not the main concern of the company
B	Energy Consulting company	. Interview with the General Manager	Active
C	Petrochemical Company	Interview with a technician manager	Active in environmental aspects and interested in energy sustainability

First of all the two new barriers are being included in the MCIR framework table of mapping barriers (see the figure in Appendix D) by applying which, the energy saving drivers will be shown in Figure 4.6.

Table 4.3 Key barriers faced by industrial organizations understudy

Key Barriers	Industrial Organizations		
	A	B	C
1. Fear of technical risks/cost of production loss			×
2. Perceived high cost of energy investments	×		
3. Lack of attitude for energy investments with long-term PB	×	×	
4. Other capital investments are more important	×	×	×
5. Uncertainty of future energy prices	×	×	×
6. Lack of experience in technology	×		
7. Lack of information in EE and energy saving technology	×	×	×
8. Lack of staff awareness/trained manpower	×		
9. Lack of energy metering	×		×
10. ESCOs lacking in specialized knowledge (empirically recorded)		×	
11. Limited access to capital/budget	×		
12. Lack of government incentives	×	×	
13. Weak policies and legislations			
14. Malversation and Corruption	×		×
15. Too many government stakeholders (empirically recorded)			
16. Resistance to change	×		
17. Space constraint (empirically recorded)			

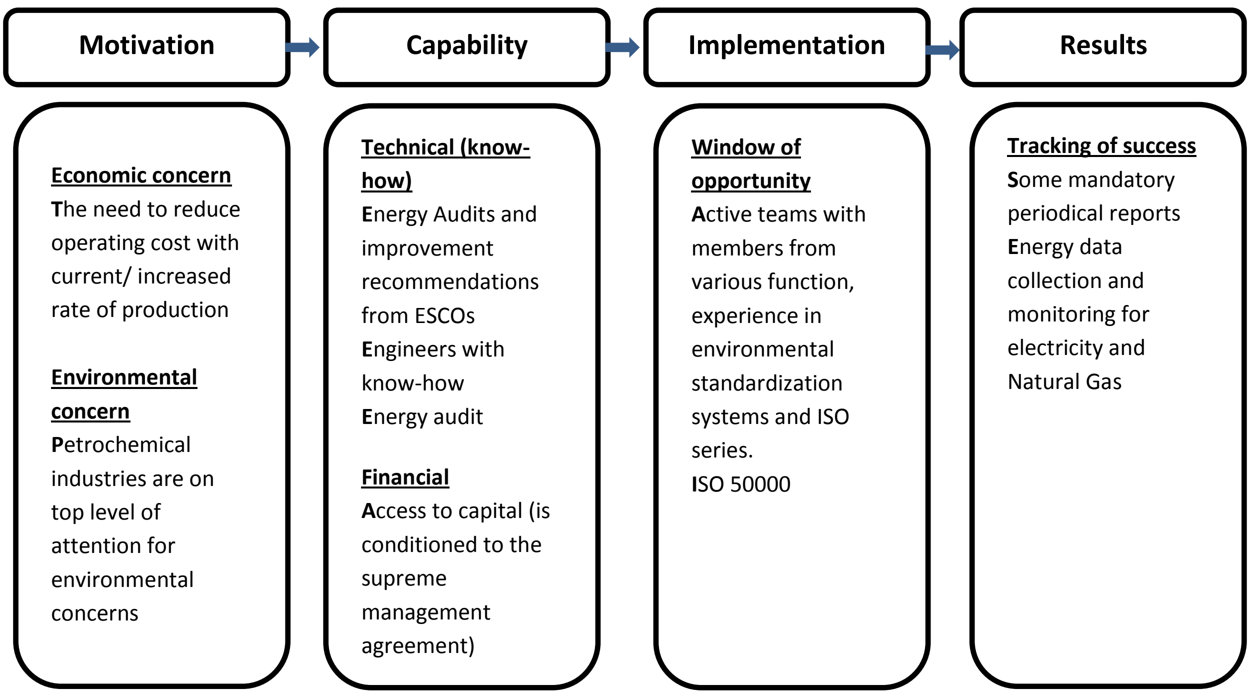


Figure 4.6 Analyzing sustainable energy launching drivers using MCIR framework in prototype petrochemical industry

In development of sustainable energy drivers, shown in Figure 4.6 here, Table 3.3 also is used. Now we can go to the activity four to identify determinant decision parameters for this company that will be used in the AHP model.

The interview and site visiting in this case recommends following criteria selection:

Criterion1. Short-term Payback
Criterion2. Need for cost reduction
Criterion3. Risk of interruption in process
Criterion4. Environmental concerns
Criterion5. Other capital investments are more important

Everything is ready to choose between three alternatives of:

Alternative1. Staying in current condition
Alternative2. Moderate change towards sustainable energy (EE)
Alternative3. Fundamental change and RETs

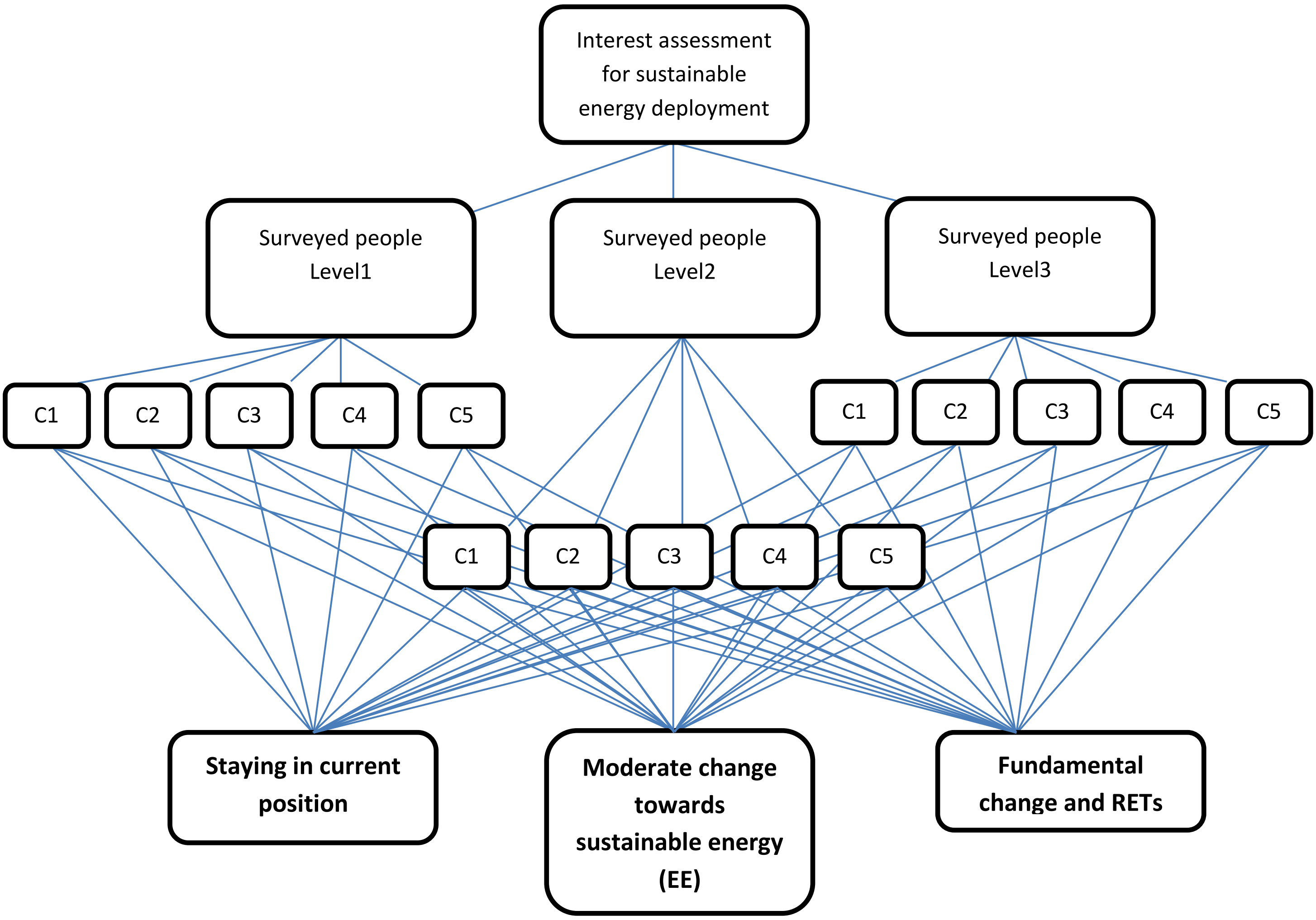


Figure 4.7 The AHP model to assess interest for Sustainable Energy deployment in prototype petrochemical industry

Making iterative Pair-Wise comparisons are the key issue for AHP (Uysal, 2010). Table 4.4 is applied to scale alternative pairwise comparison matrix and priorities.

Table 4.4 Alternative pairwise comparison matrix and priorities for prototype petrochemical industry

Criterion1 (Short-term Payback)	Alternative 1	Alternative 2	Alternative 3
Alternative 1	1	3	9
Alternative 2	0,333333	1	5
Alternative 3	0,111111	0,2	1
Sum	1,444444	4,2	15
Weights	0,668864469	0,267399267	0,063736264
Criterion2 (Need for cost reduction)	**Alternative 1**	**Alternative 1**	**Alternative 1**
Alternative 1	1	0,142857	0,2
Alternative 2	7	1	3
Alternative 3	5	0,333333	1
Sum	13	1,47619	4,2
Weights	0,073772106	0,643388869	0,282839025
Criterion3 (Risk of interruption in process)	**Alternative 1**	**Alternative 2**	**Alternative 3**
Alternative 1	1	3	6
Alternative 2	0,333333	1	5
Alternative 3	0,166667	0,2	1
Sum	1,5	4,2	12
Weights	0,626984127	0,292328042	0,080687831
Criterion4 (Environmental concern)	**Alternative 1**	**Alternative 1**	**Alternative 1**
Alternative 1	1	0,142857	0,111111
Alternative 2	7	1	0,333333
Alternative 3	9	3	1
Sum	17	4,142857	1,444444
Weights	0,056743	0,294638	0,648619
Criterion5 (Other capital investments are important)	**Alternative 1**	**Alternative 1**	**Alternative 1**
Alternative 1	1	5	9
Alternative 2	0,2	1	4
Alternative 3	0,111111	0,25	1
Sum	1,311111	6,25	14
Weights	0,73519	0,199419	0,065391

According to what already explained about AHP model in previous chapter, “Weights” here are calculated firstly by drawing matrix in which the items inside are the result of pairwise comparisons matrix divided by their column total, and then calculating “Raw Averages” in that matrix. In order to control the consistency ratio to be between 0 and 0.1 Microsoft Excel spreadsheet software is been applied. The calculations for short-term payback criteria pairwise comparison is shown in Table 4.5. The same calculations are done for other pairwise matrixes and shown the acceptable consistency ratio.

Table 4.5 Consistency Ratio calculations for the first criterion, short term payback

Short-term Payback	Alt 1	Alt 2	Alt 3	Sum	The consistency Vector
Alt 1	0,668864	0,802198	0,573626	2,044689	3,056955
Alt 2	0,222955	0,267399	0,318681	0,809035	3,025571
Alt 3	0,074318	0,05348	0,063736	0,191534	3,005109
lambda	3,029211				
CI	0,014606				
CR	0,025182				

In order to count hierarchy level effects in the analysis, Appendix E Table 1 is developed whose weights are redrawn in Table 4.6.

Table 4.6 Criterion-level weights from Appendix E Table 1

Level-Criterion weights	Criterion1	Criterion2	Criterion3	Criterion4	Criterion5
Level 1	0,053578638	0,242730614	0,43201166	0,163890035	0,107789053
Level2	0,037084131	0,154350819	0,42857372	0,266247505	0,113743829
Level3	0,042893342	0,108509086	0,41417195	0,318737054	0,115688573

Levels themselves are compared in Table 4.7 the weights of which are multiplied to Criterion-level weights matrix of Table 4.6 , and create Table 4.8.

Table 4.7 surveyed people, level pairwise comparison matrix

Level comparison	Level 1	Level 2	Level 3
Level 1	1	4	7
Level 2	0,25	1	3
Level 3	0,142857	0,333333	1
Sum	1,392857	5,333333	11
Weights	0,701437451	0,213238151	0,085324398

Table 4.8 Multiplication of level comparison weights of table 4.7 to Criterion-level weights of table 4.6

Multiply level effects	Criterion1	Criterion2	Criterion3	Criterion4	Criterion5
Level1	0,0375821	0,1702603	0,3030292	0,1149586	0,0756073
Level2	0,0079078	0,0329135	0,0913883	0,0567741	0,0242545
Level3	0,0036598	0,0092585	0,035339	0,027196	0,0098711
weighted average	0,0491497	0,2124323	0,4297564	0,1989288	0,1097329

Then the resulted weight average of Table 4.8 is multiplied to the matrix of Alternative pairwise comparison matrix weights of Table 4.9.

Table 4.9 weights of Alternative pairwise comparison matrix from Table 4.4

Alternative-Criteria weights	Alt1	ALt2	ALt3
Short term PB	0,668864469	0,267399267	0,06373626
Cost reduction	0,073772106	0,643388869	0,28283902
Interruption	0,626984127	0,292328042	0,08068783
Environmental	0,056743122	0,294637749	0,64861913
Other capital important	0,735189669	0,199418886	0,06539144

The ultimate matrix of the AHP analysis for interest assessment is shown in Table 4.10, so that according to this survey from all hierarchical levels of prototype petrochemical industry Alternative 1, staying in current condition, is the most desirable option. This result was expectable since in the primary steps of sustainability deployment, resistance to change barrier, along with other barrier, can hamper the stakeholders from perfect consideration on sustainability advantages. It should be noticed that EE, the second more wanted alternative, essentially should have been deployed before any renewable energy technology launching so that even if RETs are adopted to be deployed, EE measures should already have been executed in the industrial group. Now we can see the quantitative rates that can be used for negotiations to assign capital investment inside a company for the two alternatives of alternative2 and alternative3.

Alternative1.	Staying in current condition	0.41
Alternative2.	Moderate change towards sustainable energy (EE)	0.356
Alternative3.	Fundamental change and RETs	0.234

Table 4.10 Final Alternative Interest Decision Matrix resulted from multiplication of weighted average of Table 4.8 to the matrix of Alternative-Criteria weights of Table 4.9

Final Decision Matrix	Alt1	Alt2	Alt3
Short term PB	0,032874463	0,013142584	0,00313262
Cost reduction	0,015671578	0,136676577	0,06008414
Interruption	0,269450439	0,125629846	0,03467611
Environmental	0,01128784	0,058611928	0,12902901
Other important	0,080674465	0,021882805	0,00717559
weights	0,409958786	0,35594374	0,23409747

After activity 5, activity 6 should be completed. The key barriers of sustainable energy deployment are classified in Table 4.3. In order to send signals for stakeholders about with required policies firstly we need to identify where exactly the determinant gap inside the factory is. This aspect in this study is going to be developed in a different level of the study that MCIR framework was developed for the first time by Chai and Yeo (2012). In this study we use it for assessment inside the factory. The series of reported barriers from different departments can be assessed and instead of the number of organizations, which was in the original study, the number of departments reported respective barriers can be substituted.

Figure 4.8 shows the application of MCIR framework in gap assessment for factory level. The illustrated result refers the suitable policies that are needed to be made by different stakeholders using Table 4.4. This assessment leads to signals of the company to the stakeholders. In this case the figure shows that all stages are in the same level of development that indicates the policies have to be taken from the Motivation stage. So primarily voluntarily or obligatory agreements have to be signed by the industry understudy. Education, regulations and regarding legislation are the policies can be made by government. This industrial organization itself also should improve corporate social responsibility (CSR) among employees and use their experiences in the energy demand reduction and energy sustainability. More over customers need be motivated to demand for green products. Meanwhile and after this stage if motivation was detected to be enough, then improvement of capability for EE and sustainable energy deployment will be the priority in this industrial unit. The help of ESCOs are urgent for that step. The assessment will periodically continue to completely deploy the energy sustainability inside the company and all four stages become sufficiently accredited. Hereby the decision process that is used in activity 8 also is described.

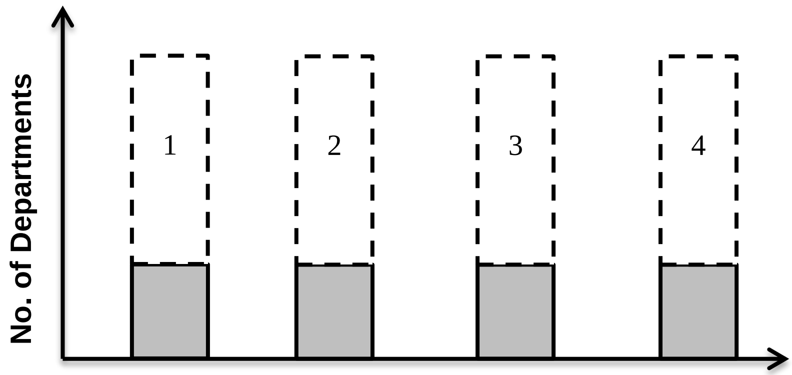


Figure 4.8 detect the gap inside the factory

The multi-disciplinary financial efficiency model for efficient investment in energy sector, which is indicated in activity seven, needs a series of activities described in the subsystem shown in the CSEL model. The root definition for the new subsystem (denoted 7.x in Figure 4.5) is being considered here.

“A system used by the DM to assign effectively the limited capital investment inside an industrial unit, considering the interest rate that already calculated in activity five and financial feasibility priorities calculated by and obtained from factory technicians or DMs.”

The respective CATWOE mnemonic to this subsystem led to the following definition:

Customer – The DM, the promoter defined by ESCO or the factory

Actor – DM in energy or Energy Systems analyzer

Transformation – Need for a financial productivity model using financial feasibility study data and interest rates data → the most appropriate financial productivity model

World view (Weltanschauung) – There is a need for a model to go beyond yes or no consensus in capital investment assignment to start sustainable energy development in industrial companies.

Owner – An institute care about sustainable energy development like Universidade de Aveiro/ Government

Environment – Requirement of the DMs, lack of sufficient time, lack of teammates, lack of funding support.

The activities constitute this subsystem include:

7.1. In this activity important and intensive energy consuming sectors in the company are identified and clarified by their complete energy consumption specifications like current annual and monthly consumption records, detailed design of process, blocks diagram for specific consumption assessment (Águas, 2009), and exploded maps of significant energy consumers. Using this information, the DM will be able to classify important energy consumption and energy cost centers.

7.2. After identification of major energy consumption centers in the company, the respected solutions will be classified into three levels from the cost view point. This classification can be done in contact with energy technicians and engineers of the company.

7.3. The Best Available Technology (BAT) here is the best technology that is available in the market like energy efficient electric motors and other efficient energy consuming equipment. These machines or equipment usually need more initial investment while their operating costs are lower in comparison. The other alternative that can be defined here for each cost level is Current Available Technology (CAT). This alternative represents renewing the machines, motors or equipment by the technology that is being used in the same place for the same reason. For example buying new electric motor with the same brand and same specification is CAT alternative choice, for energy problem solutions, when the older equipment is becoming run down and worn out. Finally we have the repair alternative for enhancement of equipment. Rewiring electric motors elaborately is an explicit example of this alternative.

7.4. In order to choose between and decide on BAT, CAT and Repair choice, the Simple Payback (SPB) and Net Present Value (NPV) of alternatives will be calculated and compared. Figure 4.9 illustrated the classification cluster described for subsystems 7.2 to 7.4, for each major energy cost center.

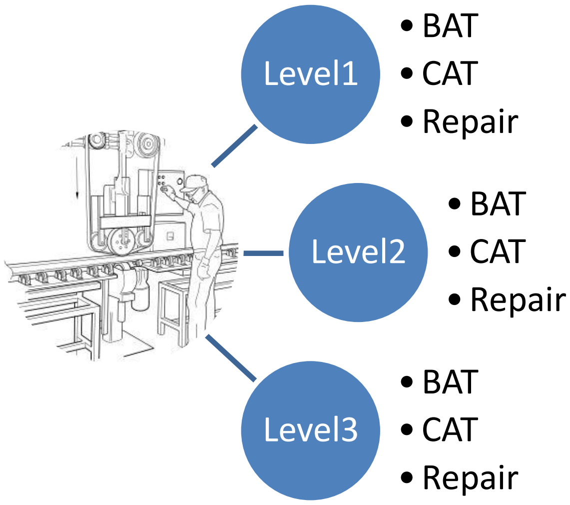


Figure 4.9, classification of sectors and financial feasibility study for each level

7.5. In order to assign capital investment to each sector-level the representing costs of them should be calculated and written. This cost will be calculated after activity 7.4 that decisions about the solutions have been taken where needed.

7.6. This activity uses the data that is obtained from activity 5 to decide on the capital investment amount, which is possible and desirable to invest, in energy sustainability. Meetings can be arranged and accountability can be used for this purpose.

AHP model also is used for the financial efficiency model of investment indicated in activity seven with some consideration. Due to lack of time for this dissertation this part only is described in methodology description, since the estimation of energy saving and emission mitigation is itself a very time consuming process.

In order to complete activity 7 in this work AHP is used in two cycles, the first cycle is for selection of the solution level for each sector, the result of which is used in the second cycle, and the second cycle in which the sector-levels will be hierarchically arranged.

Cycle 1 – The Solution Level selection: For this cycle five sectors of Machinery, Boilers, Lighting, Isolation, and Compressors are selected as the energy cost centers in which energy solutions are required. Three solution levels are defined by the energy technicians and the criteria of this analysis will be Estimated Cost of each solution, Estimated Energy Saving after the solution, and finally Estimated Emission Mitigation by that specific solution. Figure 4.10 shows the AHP diagram for ranking Solution Levels in each sector.

This may be an informal use of the AHP model since uses specific scaling of relative importance in pairwise comparison matrix of levels for each sector. For this purpose an extra table is needed to be drawn with specific data of each level of the five defined sectors. In an example table the data about three criteria of estimated cost, estimated energy saving, and estimated emission mitigation will be shown for each level of each sector. The "percent of total" column will include the data input for calculating the intensity of importance in pairwise comparisons for scaling the Level pairwise comparison matrix. This scaling is described here with an example.

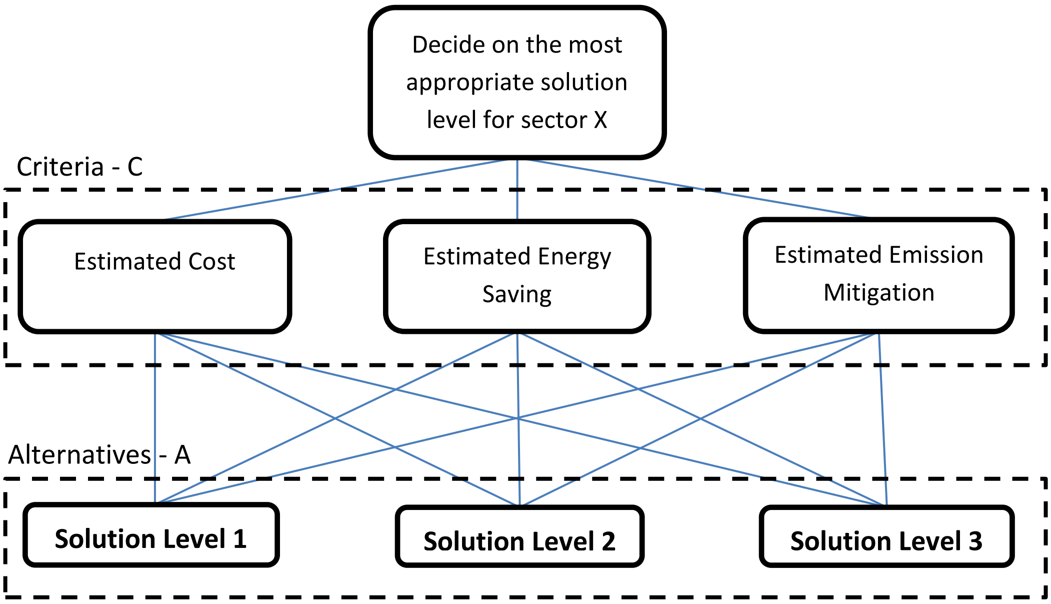


Figure 4.10 The AHP diagram for ranking Solutiom Levels in each sector, generating AxC final decision matrix (A means alternatives, C are criteria).

In a table, a sample of which is available in Appendix F Table 1 the percent of total for each level is calculated by dividing the estimated records for each sector level into the summation of level's records in that sector. Granted that the values are taken according to what that table shows, then to scale the relative importance of level 1 to level 2 from cost perspective when level 1 represents more intensity of importance, the scale will be (Level2/level1)^2. Note that better result from cost perspective is lower percentage of cost inclusion. The exponential form is used here for better distinguishing the intensity of importance in each cell.

Vice versa the better result from the energy saving and emission mitigation viewpoint is the higher percentage so that for energy in same comparison, level1 with level2, the scale will be (Level1/level2) ^2 that gives the result of (55/35) ^2 that is approximately 2.5. The same concept for better result and formulation is used for emission.

After calculation of weights in pairwise comparison matrix, like matrix of Appendix F Table 2, for each level regarding each criterion in a formal sequence of AHP model which already discussed it comes to the comparison matrix of criteria which are the preference evaluation of cost, energy saving, and emission mitigation (see Appendix F Table 3).

The final decision matrix will conclude the hierarchy of levels of each sector. The most desirable level of each sector represents the solution of each sector in a new table which will be used in cycle 2.

Cycle 2 – Similar analysis to cycle 1 is taken part for energy sector hierarchy selection in this cycle.

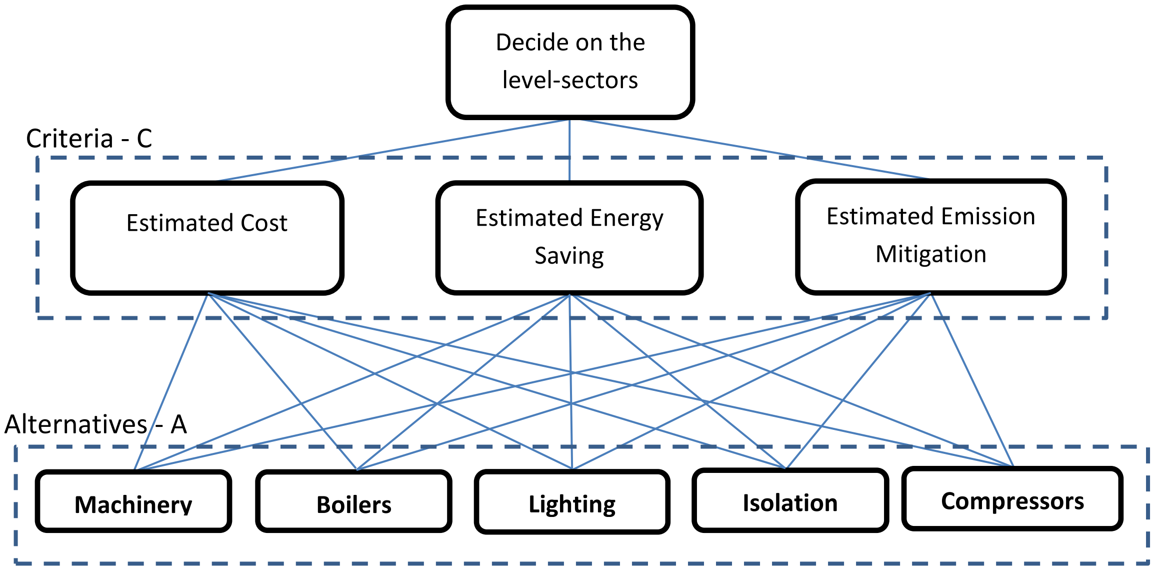


Figure 4.11 the AHP diagram For ranking A considering C. A represents Alternatives and C represents Criteria here

Appendix G Table 2 shows an example of the required pairwise matrix in this cycle that uses Appendix G Table 1 to calculate the scale of relative importance similar to the cycle 1. In this cycle weights obtained from Appendix F Table 3 will be used to be multiplied in weights of sector pairwise comparison matrix of Appendix G Table 2.

The outcome of cycle 2 will be the preference hierarchy of sectors. Cycle 1 together with cycle 2 will give us the sector level preferences.

Another part of activity 8 is ready to be done. The amount of money taken from multiplication of interest analysis rate that is been decide on activity 7.6 will be assigned in activity 8. The sector-levels will take the capital investment from top hierarchical level to lower one as shown in Figure 4.12. The resulting assignment is expected to be financially productive, this means that the most energy saving and emission mitigation is obtained from lowest possible funding amount.

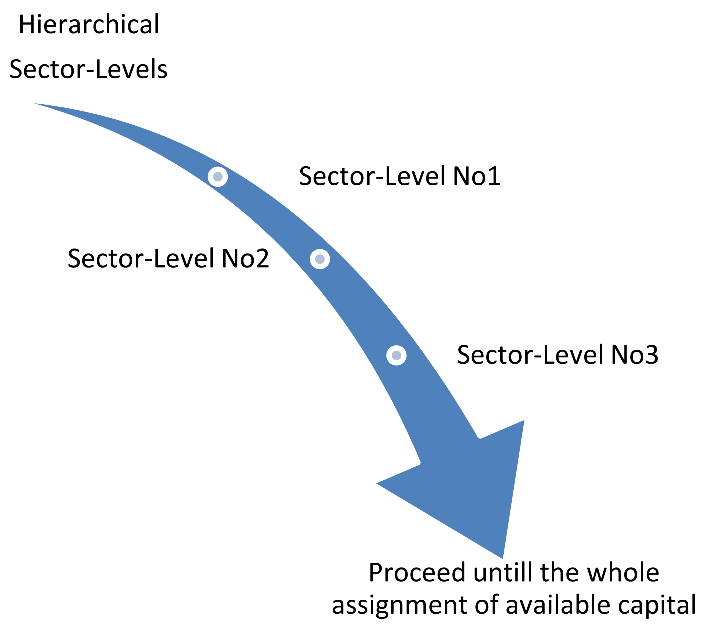


Figure 4.12, capital investment assignment hierarchy

4.3. UML and Financial Efficient Capital Investment Model of SSM

To better describe the roles in Activity 7 Use-case diagram of financial efficient model is shown in Figure 4.13. As illustrated in that figure new roles of analyzer, responsible agent and Board of Directors are identified here. According to what the Use-case diagram shows an analyzer is responsible for attractiveness analysis that is named “Activity7” in SSM model of the CSEL framework (see Figure 4.5). Analyzer here can be a DM or system manager both from inside of the company or an agent of an ESCO from outside of the company. But yet the final decision making should be through board of directors or in agreement with them, since the supervision and support of supreme management is vital for project implementation.

The other flow of information system starts with energy sector and cost center definition. Activity Diagram shown in Figure 4.14 starts from this point. This use-case by itself requires a basic and detailed study on energy system but this lack of information can be solved by asking from existent technicians with some acceptable tolerance in accuracy. This tolerance can be reduced and the estimation can be stricter in the following cycles of the learning system.

The same technician or group of technicians and related engineers, with the accompaniment of financial experts and agents from procurement headquarter can propose three levels of solution for each sector or cost center. These sectors and levels should deliberately be identified in such case that neither to be too small nor to be too huge in size and inclusion. The experience will adjust the correct form of division in the sectors and solution levels. Also in some cases there might be only one level of solution without capability to diversify in two or three. These sectors will be counted directly as top level of the respected sector in the sector-level tables for comparison. Another method is to assign worse values in the empty places of calculations so that they would automatically be withdrawn. Also the Activity Diagram of Figure 4.14 can define the software in a method to prevent the problem of taking one level for special sectors.

The same responsible agents of the company with financial background in their studies or trainings can do the financial evaluations for BAT, CAT, and Repair for deciding which one to choose. Three Use-cases of “search for BAT, CAT, and Repair information”, “Determine SBP and NPV of BAT, CAT, and Repair” and “Decide investment related to each level” represent financial feasibility study and evaluation in this diagram. These use-cases can be merged in the use-case of level definition if the DM prefers. The remaining Use-cases can be done automatically by software.

Activity Diagram describes activities and actions taking place in the model. These diagrams can be used for further development of system and software development purposes which takes the preferences of DMs in different stages and helps them in making more rational decisions that can be acceptable from different aspects regarding different criteria that every company may encounter.

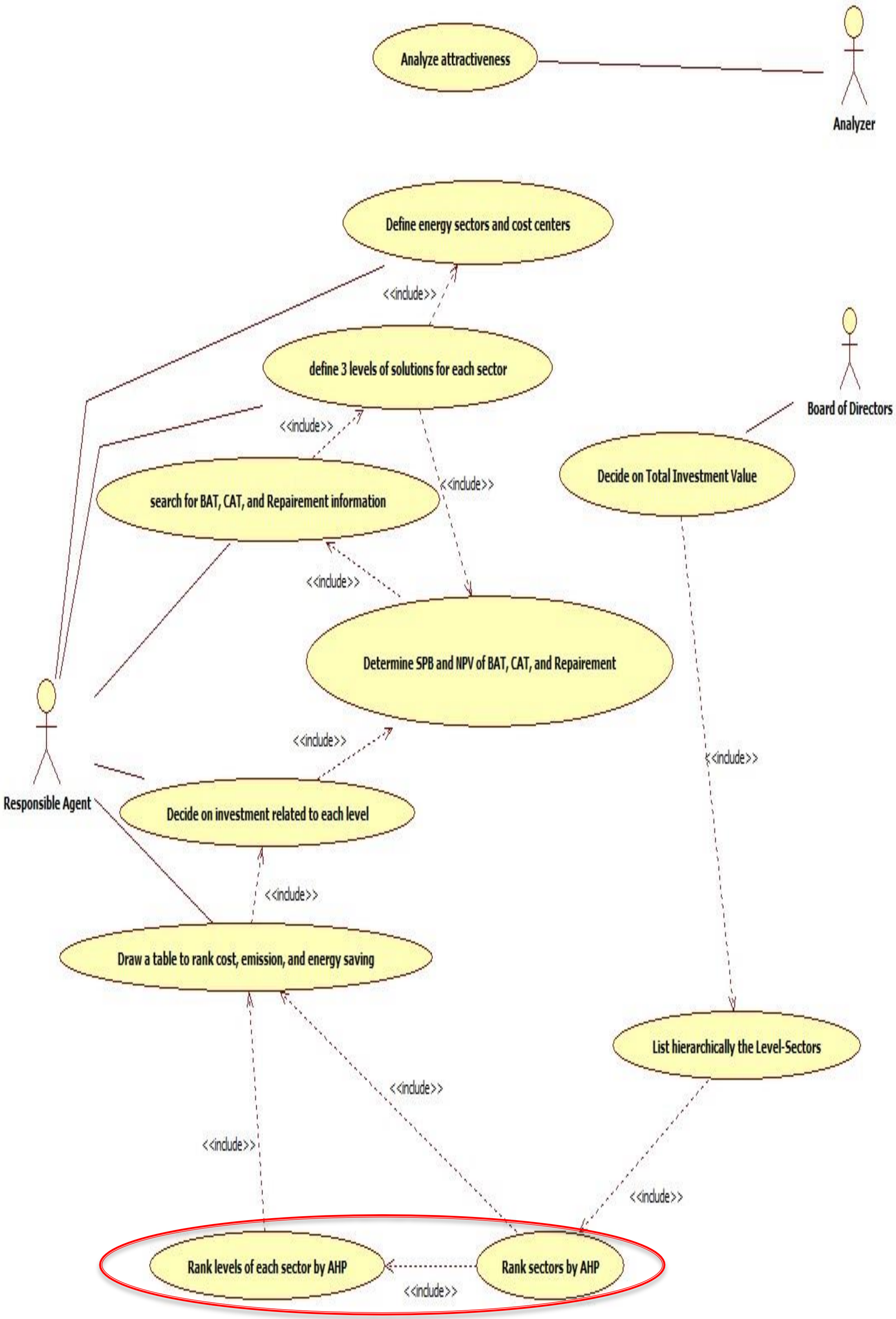


Figure 4.13, Use-case of financial efficient capital investment model of activity 7 using StarUML software and the application of AHP is illustrated in an oval shape

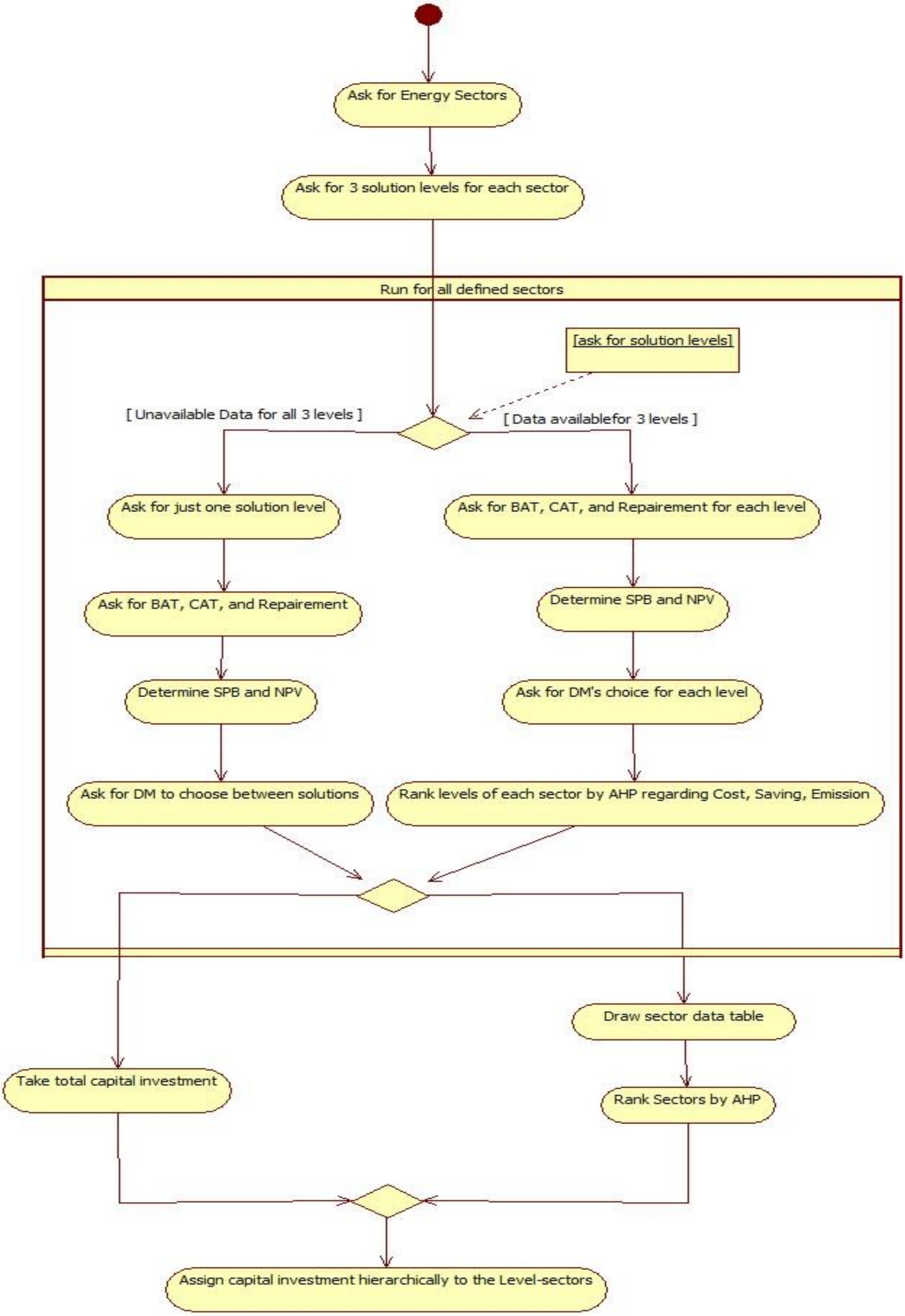


Figure 4.14 Activity Diagram for financial efficient capital investment model of activity 7 using StarUML software

Chapter 5. Conclusion, limitations and future study

In order to launch Sustainable Energy in Iranian industries primarily its complicated structure had to be addressed and clarified. Successively its key components, stakeholders, relations, and assumptions had to be taken to prepare comprehensive information for the future studies. The SSM was detected to be an effective tool for this purpose. Furthermore it prepared a suitable base to describe and arrange other solutions and methods as a coherent whole. The methods that are used as components of CSEL framework still has to be investigated and analyzed to verify their appropriateness in contrast with other plausible methods and for their consistency with the whole. It is believed that in some cases other multi-objective decision making methods and Meta-heuristics also can be helpful in this field.

This work is not a “typical” application of SSM. The comparison and debate stages of the study needed future feedbacks and further meetings, along with implementing the CSEL model. Only in that case the whole model will be suitably fitted for better deployment of energy sustainability in industrial section. However, system thinking helped considerably in clarifying the problem situation and lined the route for future studies in a clear defined structure.

Also in the next SSM learning cycles the barriers introduced in the MCIR classification of Appendix D can be changed or augmented considering the Iranian industrial environment and three goals of sustainable energy development, ‘trilemma’, for proposing stable, affordable, and environmentally-sensitive energy systems.

Addressing energy efficiency needs a holistic view and each specific aspect of the problem should be addressed by individual methods that are covered by a holistic system methodology. Moreover this framework has the potential of working as a down to up alarming system, which prepares signals for policy makers of the company and higher levels of industrial sectors like governments and ESCOs. MCIR framework application in this work helped to gain the ability of checking out the system periodically for barriers and gaps in order to mitigate them.

Another objective of this work was structuring a model to help financial decision makers to trigger the energy sustainability measures in almost every financial condition of a company. The multi-disciplinary financial efficiency model of investment, which is shown by Activity 7 in purposeful activity model of MCIR framework, captures the interest rate for energy sustainability initiatives from different levels of stakeholders and decision makers and uses them to assign the capital investment of the industry on energy sustainability efficiently. Usually industries are reluctant to invest or even start energy sustainability initiatives like ISO 50001 due to fear of possible costs that they imagine such initiatives might have for the company. Applying this model in a prototype petrochemical industry shows the efficacy part of the analysis. This means that the efficiency and effectiveness of this model is needed to be analyzed in the next cycles of study and by future work. The application of the model from efficacy point of view helped clarification of different cost levels of energy sustainability measures, which motivates the financial DMs to assign budget in both culturally desirable and financially plausible state. AHP model as a structuring method took interests on different alternatives and helped in multi-variation and multi criteria decision making process.

The Use-case and Activity Diagram of Unified Modeling Language (UML) was useful in specifically describing the financial efficient model of CSEL framework that identifies where the decisions are taken and by which roles. At the same time depicts the information flow in that model.

Although lack of time, limitation of group members and lack of budget for this project hinder further study and implementation of this framework, but the whole attempt of the author was to line the rout and help the decision makers to have a holistic view on structuring a framework for this purpose in Iranian Industry sector and Industry sectors of other countries that may have same barriers of sustainability deployment in their industries, even though the whole framework is been structured in a coherent form that can be pursued and completed systematically.

In the future work the possibility of other heuristic and meta-heuristic methods have to be analyzed in the multi variation decision makings for this framework. Moreover the comparison, debate and action to improve stages of SSM have to be done by meetings and along with implementation of the framework.

Also same analysis can be done in other energy sectors of energy that are transportation and household. After enough debate and cyclical review of the framework in the systematic cyclical learning system of SSM, the whole framework can be compiled by UML to structure its information system for software development purposes.

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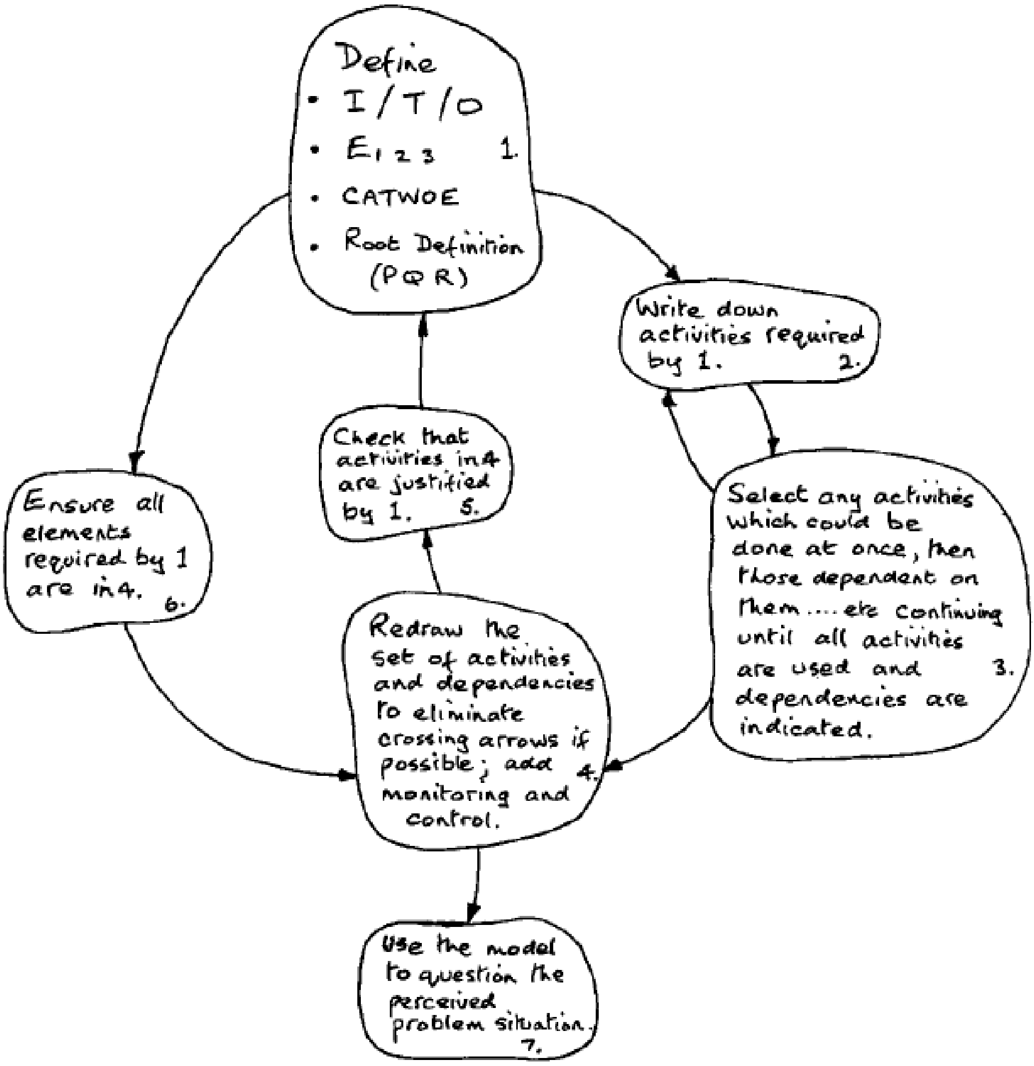
Appendix A

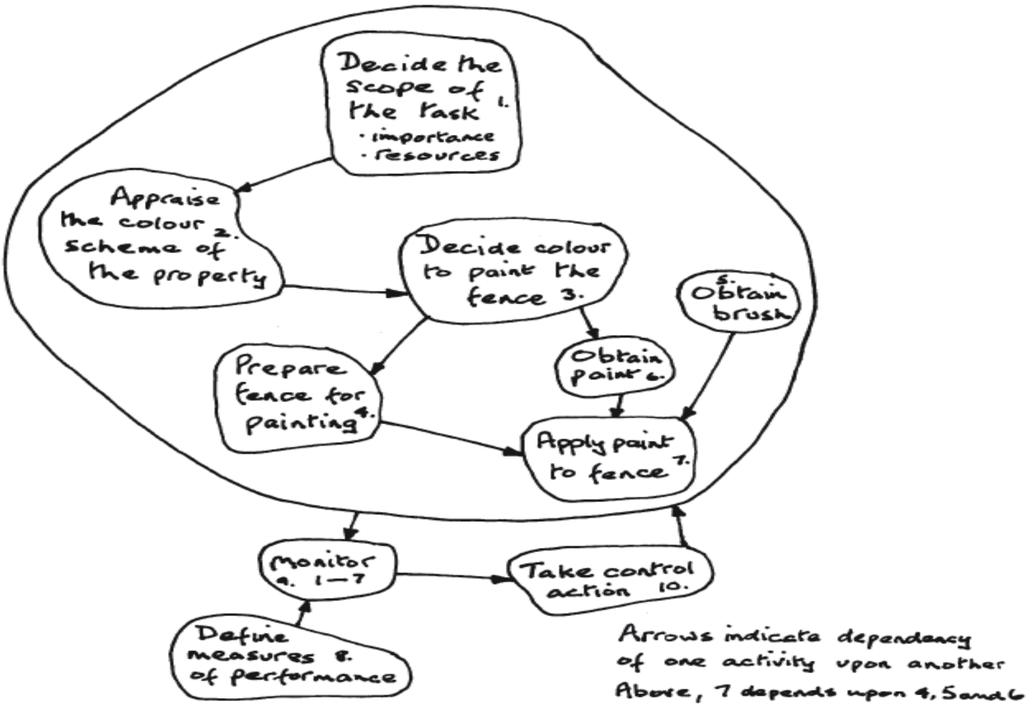
Appendix A Figure 1 the basic outline of Soft Systems Methodology (Checkland & Poulter, 2010)

Appendix B

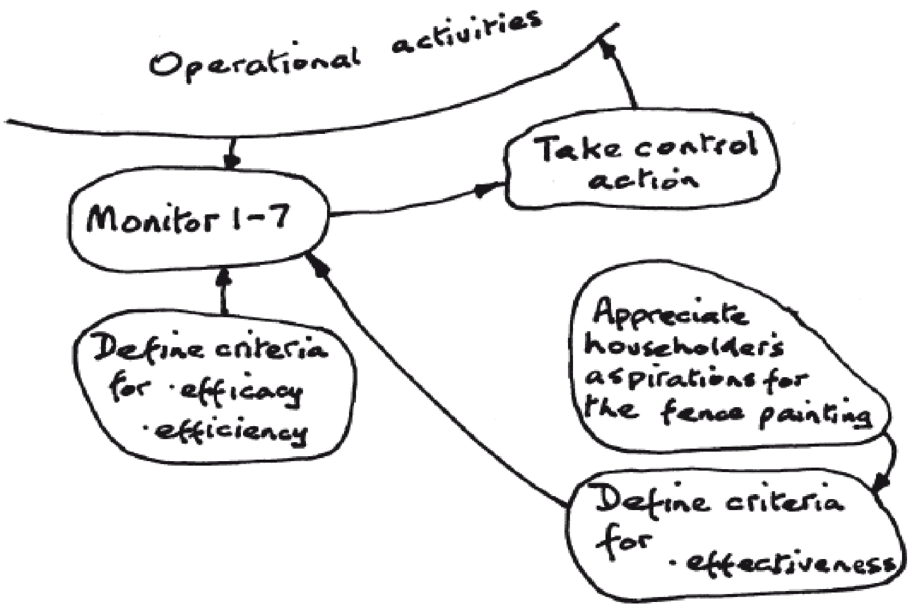


Appendix B Figure 1 the process of modeling in SSM, embodying the logic of Building a Purposeful Activity Model

Appendix C

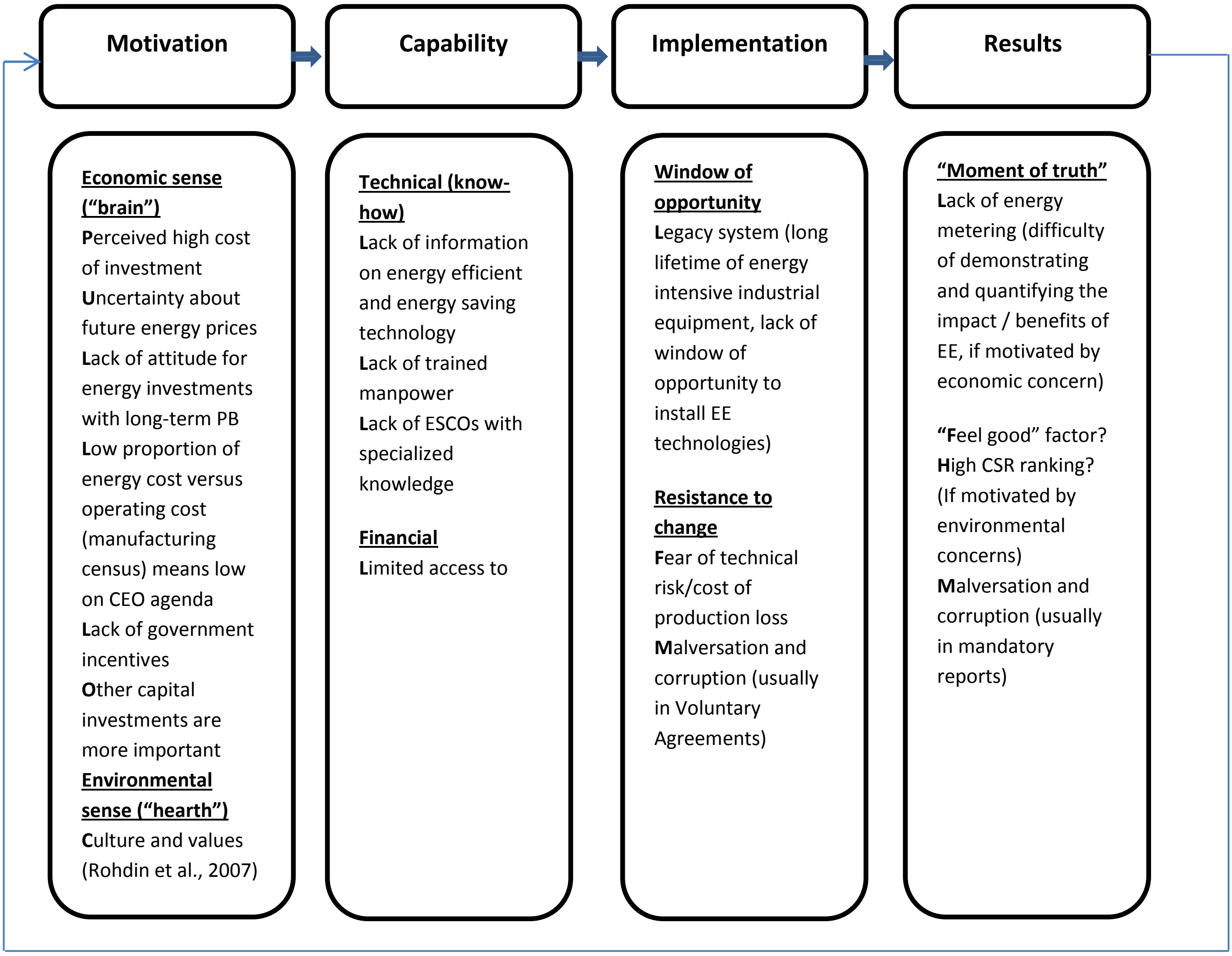


Appendix C Figure 1 a simple example of an activity model: a system to paint the garden fence by hand painting



Appendix C Figure 2 variant of monitoring and control part of the model in the garden fence painting sample
(Checkland & Poulter, 2010)

Appendix D



Appendix D Figure 1 Mapping barriers into the MCIR framework according to Chai and Yeo (2012) with two new barriers identified

Appendix E

Appendix E Table 1 Criteria pairwise comparisons by three levels of hierarchy inside company

Criteria comparison Level1	Short-term PB	Need for Cost Reduction	Risk of Process Interruption	Environmental concerns	Other capital investments are more important
Short-term PB	1	0,333333333	0,142857143	0,333333333	0,333333333
Need for Cost Reduction	3	1	0,333333333	3	3
Risk of Process Interruption	7	3	1	3	3
Environmental concerns	3	0,333333333	0,333333333	1	3
Other capital investments are more important	3	0,333333333	0,333333333	0,333333333	1
Sum	17	5	2,142857143	7,666666667	10,33333333
Weights	0,053578638	0,242730614	0,43201166	0,163890035	0,107789053
Criteria comparison Level2	**Short term PB**	**Need for Cost Reduction**	**Risk of Process Interruption**	**Environmental concerns**	**Other capital investments are more important**
Short-term PB	1	0,333333333	0,111111111	0,142857143	0,2
Need for Cost Reduction	3	1	0,333333333	0,333333333	3
Risk of Process Interruption	9	3	1	3	3
Environmental concerns	7	3	0,333333333	1	3
Other capital investments are more important	5	0,333333333	0,333333333	0,333333333	1
Sum	25	7,666666667	2,111111111	4,80952381	10,2
Weights	0,037084131	0,154350819	0,428573716	0,266247505	0,113743829
Criteria comparison Level3	**Short term PB**	**Need for Cost Reduction**	**Risk of Process Interruption**	**Environmental concerns**	**Other capital investments are more important**
Short-term PB	1	0,333333333	0,142857143	0,142857143	0,333333333
Need for Cost Reduction	3	1	0,333333333	0,166666667	1
Risk of Process Interruption	7	3	1	3	3
Environmental concerns	7	6	0,333333333	1	3
Other capital investments are more important	3	1	0,333333333	0,333333333	1
Sum	21	11,33333333	2,142857143	4,642857143	8,333333333
Weights	0,042893342	0,108509086	0,414171946	0,318737054	0,115688573

Appendix F

Appendix F Table 1 data gathered to rank sector levels in percent of total of that sector

Sector	Level	Estimated Cost	Percent of total	Estimated Energy Saving	Percent of total	Estimated Emission Mitigation	Percent of total
Machinery	Level1						
	Level2						
	Level3						
sum	3						
Boilers	Level1						
	Level2						
	Level3						
sum	3						
Lighting	Level1		20		55		30
	Level2		40		35		40
	Level3		40		10		30
sum	3						
Isolation	Level1						
	Level2						
	Level3						
sum	3						
Compressors	Level1						
	Level2						
	Level2						
sum	3						

Appendix F Table 2 pairwise comparison matrix of each level regarding the criteria

Lighting cost	L1	L2	L3
L1	1	4	4
L2	1/4	1	1
L3	1/4	1	1
Weight			
Lighting energy saving	L1	L2	L3
L1			
L2			
L3			
Weight			
Lighting emission	L1	L2	L3
L1			
L2			
L3			
Weight			

Appendix F Table 3 criteria comparison matrix of cycle 1

Criteria Comparison	Cost	Energy saving	Emission mitigation
Cost	1	2	9
Energy saving	1/2	1	2
Emission mitigation	1/9	1/2	1
weight			

Appendix F Table 4 final decision matrix resulting in the levels ranking.

Final Decision Matrix	Level1	Level2	Level3
Cost			
Energy saving			
Emission mitigaiton			
weight			

Appendix G

Appendix G Table 1. Table of data that takes the result of cycle 1 as most prefered level of each sector

Sector-level	Estimated Cost	Percent of total	Estimated energy saving	Percent of total	Estimated emission mitigation	Percent of total
Machinery						
Boilers						
Lighting						
Isolation						
Compressors						
Total						

Appendix G Table 2 Pairwise comparison matrix of sectors for cycle 2

Cost	Machinery	Boilers	Lighting	Isolation	Compressors
Machinery					
Boilers					
Lighting					
Isolation					
Compressors					
Energy saving	Machinery	Boilers	Lighting	Isolation	Compressors
Machinery					
Boilers					
Lighting					
Isolation					
Compressors					
Emission mitigation	Machinery	Boilers	Lighting	Isolation	Compressors
Machinery					
Boilers					
Lighting					
Isolation					
Compressors					