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# VALUE ENGINEERING: OPPORTUNITIES AND CHALLENGES[†]

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## ABSTRACT

The United Nations Sustainable Development Goals (SDGs) are targets for global development adopted in September 2015, set to be achieved by 2030.

SDG 1 is clear: *By 2030, eradicate extreme poverty for all people everywhere*. The proportion of the world's population in extreme poverty declined from almost everyone two centuries ago to below 10% in 2015.

Projections by Crespo Cuaresma *et al*. published in *Nature* in 2108 show that the number of people in extreme poverty will fall to about 450 million people by 2030. To fully eradicate extreme poverty for all people everywhere may be equivalent to saving approximately US$250 billion annually which is less than 0.3% of the world gross domestic product (GDP). Based on worldwide experience, value methodology can facilitate average saving of about 20–30% of total project costs in developing countries and consequently value engineering (VE) can facilitate the saving required for ICID Vision 2030. The 'transition generation' is the most important hope that humanity has for coping with mega challenges of the twenty-first century. The 'transition generation' must be inspired and empowered. In this context, it is envisioned that value methodology will be proved to be an effective and efficient tool. © 2020 John Wiley & Sons, Ltd.

KEY WORDS: Sustainable Development Goals; ICID Vision 2030; value engineering; teamwork synergy; transition generation

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## RÉSUMÉ

Les objectifs de dévelopement durable des Nations Unies (ODD) sont des objectifs de dévelopement mondial adoptés en Septembre 2015 et qui devraient être atteints d'ici 2030.

L'objectif de dévelopement durable n° 1 est clair: d'ici 2030, éliminer l'extrême pauvreté pour tous, où que ce soit. La part de la population mondiale dans l'extrême pauvreté est passée de presque tout le monde il y a deux siècles à moins de 10% en 2015.

Projections de Crespo Cuaresma *et al*. publiés dans Nature en 2108 montrent que le nombre de personnes vivant dans l'extrême pauvreté est prévue de tomber à environ 450 millions d'ici 2030. Éradiquer totalement l'extrême pauvreté pour tous peut équivaloir à économiser environ 250 milliards de dollars par an, ce qui est inférieur à 0,3% du produit intérieur brut (PIB) mondial. Sur la base de l'expérience acquise dans le monde entier, la méthodologie de la valeur peut permettre une économie moyenne d'environ 20 à 30% des coûts totaux du projet dans les pays en dévelopement et, par conséquent, l'ingénierie de la valeur peut faciliter les économies requises pour la Vision CIID 2030. La *génération de transition est* le plus important espoir de l'humanité pour faire face aux défis colossaux du 21éme siécle. La *génération de transition* doit être inspirée et responsabilisée. Dans ce contexte, il est envisagé de démontrer que l'ingénierie de la valeur est un outil efficace et efficient. © 2020 John Wiley & Sons, Ltd.

MOTS CLÉS: objectifs de développement durable; Vision CIID 2030; ingénierie de la valeur; synergie du travail déquipe; génération de la transition.

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[†]Ingénierie de la valeur: opportunités et défis.

## 1. INTRODUCTION

The twentieth century was one of explosive population growth, resulting in unprecedented impacts. At the start of the twenty-first century, humankind finds itself on a non-sustainable course—a course that, unless changed, will lead to catastrophes with terrible consequences. We are at an extraordinary crossroads of human history. Our actions or failure to act during the coming decades will determine the fate of human civilization for centuries to come (Martin, 2007).

This is a MAKE or BREAK century! In this context, the rate of technological progress should outrun environmental damage and increasing demands.

Undoubtedly, water is and will be the prime issue in the twenty-first century and water engineers are key players in coping with most of the twenty-first-century challenges.

Extreme water-related events, floods and droughts, are natural phenomena, and will continue to happen. The risk is likely to grow in the twenty-first century, heralded as the age of water scarcity, while flood losses also show a rising tendency. Recent climate variability and change seem to have adversely affected flood and drought hazards in several areas and this tendency is likely to continue. Therefore, coping with these water-related challenges requires major technical jumps and innovations (Fraiman, 2010).

## 2. ICID VISION 2030 GOALS AND STRATEGY

The ICID vision for 2030 is 'A water-secure world free of poverty and hunger through sustainable rural development' (ICID, 2017). In order to feed the 9 billion people in 2050 under current market, institutional and economic systems, the world must produce 40% more food by 2050 and 100% more in developing countries. These challenges have to be met with limited land and water resources, using less energy, fertilizer and pesticides and under climate change uncertainties while coping with rapid developments in many other related spheres. In short, we must do MORE with LESS.

The ICID Vision for 2030 sets out six organizational goals:

- *Goal A*. Enable higher crop productivity with less water and energy;
- *Goal B*. Be a catalyst for a change in policies and practices;
- *Goal C*. Facilitate exchange of information, knowledge and technology;
- *Goal D*. Enable cross-disciplinary and inter-sectoral engagement;
- *Goal E*. Encourage research and support development of tools to extend innovation into field practices;
- *Goal F*. Facilitate capacity development.

An example of the ICID strategy for achieving these goals is described below for Goal A. The ICID network would advocate with national governments and funding agencies to make strategic choices that favour higher crop production using less energy and water, thereby contributing to sustainable agricultural water management and net increase in farmers' income and profits. This is proposed to be achieved by implementing the following strategies:

- *Strategy 1.1* Modernizing irrigation systems;
- *Strategy 1.2* Improving operation and maintenance (O&M) of irrigation systems;
- *Strategy 1.3* Implementing water-saving techniques and technologies;
- *Strategy 1.4* Promoting institutional reforms;
- *Strategy 1.5* Supporting water productivity enhancement;
- *Strategy 1.6* Improving performance of irrigation systems;
- *Strategy 1.7* Using wastewater or poor-quality water for irrigation;
- *Strategy 1.8* Encouraging participatory management of irrigation systems.

ICID National Committees (NCs) will be the key players in working towards this goal through their national stakeholders. ICID Technical Working Groups will provide the key inputs crystalized through shared experiences to achieve this goal.

### *2.1. What is value engineering?*

There are many definitions of value engineering (VE). Some of them are presented as follows:

- VE is a process where a team of independent engineers come in and review a project and look for opportunities to modify the design to save cost;
- In general, VE is the systematic application of recognized techniques by an independent, multidisciplinary team, to identify the function of a product or service, establish a worth for that function and generate alternatives. This process considers all project objectives, such as safety, operational and environmental commitments while trying to reduce total ownership costs;
- the VE process is a peer review that allows an owner to get a second look at the project design by doing it in the early stages of design and allows greater room to make greater changes;
- VE essentially pulls together a team of specialized engineers who are familiar with the type of project in question and they look at different ways to increase the value of the project and at the same time save the owner money;

- clients must turn to outside firms to make sure that there is an objective source looking at all the costs along the way to make sure that they are kept within reason and clients do not rely on one source to give them all of their news;
- by going outside for an independent team for VE the client gets a second set of eyes, a group of experienced engineers who have seen things done differently, have other experiences than the design team already selected; the client has an opportunity to find ways that maybe the design team either has not seen or did not think of, to improve the project;
- VE has proven to be a sound approach that can reduce project costs, improve project quality, eliminate unnecessary design elements, foster innovation and improve productivity. It is a process that has proven to produce huge benefits for projects both large and small (Emami and Razavi, 2005, Emami, 2013).

### *2.2. VE, an effective and efficient tool for the challenges of the twenty-first century*

The main theme of this paper is the effectiveness and efficiency of VE as a proven productivity technique for enhancing water projects. This is supported by the following arguments:

- *Rigorous reviews*. The incredible complexity of today's projects and the expenses they generate, demand a system for re-examining ideas and performance. National Aeronautics and Space Administration (NASA) projects are considered the most technically complicated projects in the world. As shown in Figure 1, rigorous reviews are the key to the NASA project management success model. And VE may be considered one of the most rigorous reviews utilized;
- *Proven technique*. Based on the results of thousands of VE studies conducted in all technical disciplines, VE is a proven technique if properly applied. Total savings of US$29.3 billion in some 6965 highway projects in the USA (Figure 1) and savings of up to 48% in irrigation projects in Japan (Table I) illustrate this fact;
- *Extensive applications*. Value methodology can successfully be applied in order to improve products (value analysis (VA)), projects (value planning (VP) and VE) and processes and procedures (value management (VM)). VECPs (value engineering change proposals) are also used by contractors in the context of incentives laws;
- *Unbelievable return on investment* (*ROI*). The ROI of VE studies can be in the range of 100–1000 in developing countries. So, with minimum expense, very large benefits can be reaped if VE is properly applied. Therefore, VE is affordable for poor countries;
- *Sustainable irrigated agriculture*. In 1999, the USA government published a guide entitled *Sustainable Federal Facilities*. The federal government owns approximately 500 000 facilities and their associated infrastructures worldwide. This facilities' inventory represents a significant capital asset portfolio valued at more than US$300 billion. Upwards of US$20 billion are spent annually on acquiring or substantially renovating federal facilities. The main theme of the mentioned guide is integrating VE, life cycle costing and sustainable development (Federal Facilities Council, 2001). By the same token, VE can be used to ensure sustainability of irrigated agriculture, which is the vision of ICID;


Figure 1. NASA project management success model (Rogers, 2008)

Table I. VE saving in irrigation projects in Japan (Emami and Emami (in preparation))

| Project title | Total cost in million US$ | VE saving in million US$ | VE saving in % |
|---|---|---|---|
| 1 National reclaim and construct project in south Kimotuski area | 103 | 12 | 11.5 |
| 2 Rehabilitation project of Miagawa irrigation area | 76 | 31 | 41.6 |
| 3 Rehabilitation project of Ryoutiku Plain irrigation area | 27 | 13 | 47.9 |
| 4 Rehabilitation project of Yahagi-gawa irrigation system | 70 | 8 | 11.8 |
| 5 Japanese national irrigation and drainage project of So-Hokubu area | 28 | 8 | 29.3 |
| **Total or average** | **304** | **72** | **23.7** |

- *Inspiring and empowering the transition generation*. As mentioned above, the transition generation has a key role in the context of the current mega problems. VE can be utilized to inspire and empower them;
- *Enhancing organizational learning*. Figure 2 illustrates the outcome of the research conducted on organizational learning (OL) by NASA. The main components of OL in NASA are shown in Figure 3.

As VE is a challenging task in which one can learn from others and their mistakes, it can enhance OL considerably:

| YEAR | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | Sum |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Number of VE Studies | 369 | 431 | 385 | 388 | 378 | 377 | 344 | 324 | 300 | 242 | 316 | 388 | 427 | 402 | 378 | 352 | 281 | 215 | 135 | 198 | 160 | 175 | 6965 |
| Cost of VE Studies Plus Administrative Cost (Million $) | 5 | 7 | 7 | 8 | 8 | 9 | 8 | 7 | 10 | 8 | 12 | 12 | 17 | 14 | 13 | 12 | 9.8 | 8.7 | 6.4 | 7.3 | 6.6 | 7.3 | 201.3 |
| Estimated Costs of Projects Studied (BillionsS) | 10 | 17 | 19 | 16 | 19 | 21 | 20 | 19 | 32 | 22 | 25 | 30 | 29 | 34 | 32 | 30 | 23 | 21 | 14 | 14 | 21 | 23 | 490 |
| Value of Approved Recommendations (BillionsS) | 0.5 | 0.8 | 0.8 | 1.1 | 0.9 | 1 | 1 | 1.1 | 3.2 | 1.7 | 2 | 2.5 | 1.7 | 2 | 1 | 1.1 | 1.2 | 1.7 | 0.8 | 0.9 | 1.1 | 1.1 | 29.3 |
| Return on Investment | 1:106 | 1:117 | 1:113 | 1:145 | 1:119 | 1:116 | 1:120 | 1:145 | 1:325 | 1:240 | 1:157 | 1:205 | 1:100 | 1:146 | 1:80 | 1:96 | 1:118 | 1:200 | 1:129 | 1:119 | 1:159 | 1:157 | 1:146 |
| % of Project Costs Saved | 8.35 | 4.47 | 4.49 | 6.94 | 4.58 | 5.06 | 5.42 | 5.97 | 10.09 | 8.29 | 7.95 | 8.53 | 5.84 | 5.79 | 3.12 | 3.78 | 5 | 8.32 | 6.14 | 6.20 | 5 | 5 | 6.12 |

Figure 2. Summary of past VE saving federal-aid highway projects (1997–2018) in the USA https://www.fhwa.dot.gov/ve/ [Colour figure can be viewed at wileyonlinelibrary.com]

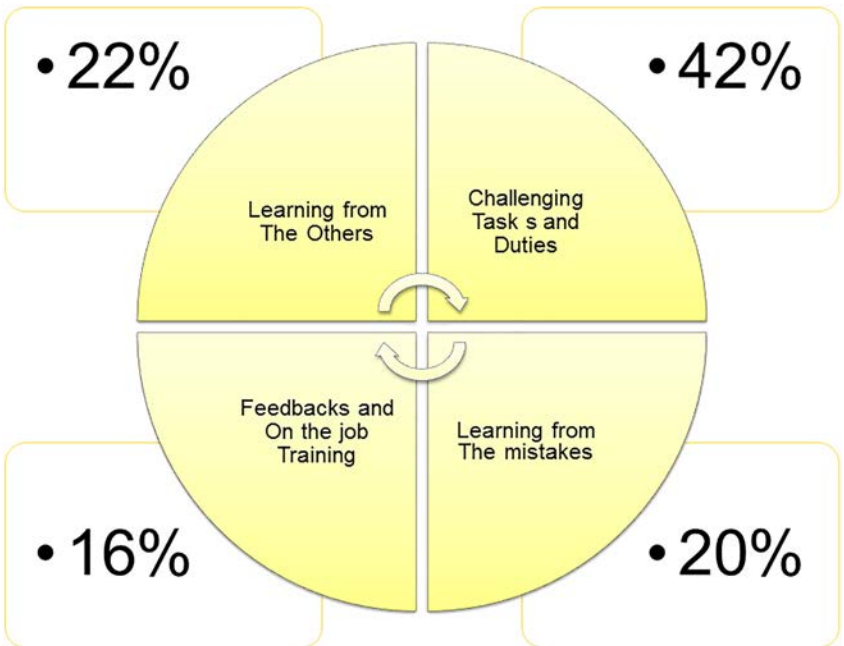


Figure 3. The components of organizational learning in NASA (Rogers, 2008) [Colour figure can be viewed at wileyonlinelibrary.com]

- *Matches with the results of research conducted on creativity and teamwork*. It can be demonstrated that VE methodology closely corresponds with the results of research conducted on creativity, problem solving and teamwork (Emami and Emami (in preparation));
- *Facilitating information technology* (*IT*) *and non-structural approaches*. IT and non-structural approaches have demonstrated great and increasing potential in enhancing the value of various projects and products. Function-oriented VE can facilitate extensive application of IT and non-structural approaches in water projects as demonstrated by the outcome of many VE studies;
- *Buttressing peace*. Water conflicts raging over scarce water resources can aggravate the already complex mega problems in many developing countries. On the other hand, it can be envisioned that water can be used as 'blue peace' if win–win scenarios can be achieved through mutual cooperation and creative schemes proposed by VE teams (Figure 4). In recent years, weak water resources management and poor projects are considered the main platform for recent conflicts in the Middle East. The pillars of positive peace are illustrated in Figure 3.
- *From novel ideas to standard practice*. Based on worldwide experience, many novel ideas and recommendations of VE studies will become standard practice in time and many projects would be enhanced with very little effort;
- *Improved job skills*. In 2016 the World Economic Forum published the top 10 job skills for 2015 and 2020 (Figure 5). As illustrated by Figure 5, the top skills such as complex problem solving, critical thinking, creativity, people management, coordinating with others, emotional intelligence (EQ) etc. correlate closely with VE methodology and can be improved substantially by attending VE training workshops and value studies;
- *Unbiased design*. All designs are biased because of the expertise, experience and orientations of the designers and the clients. The VE methodology is based on the synergy and creativity of an independent team. The independence and outside perspective of VE teams would reduce bias in the design and consequently would result in saving and enhanced benefits for the projects;
- *Win–win scenarios*. In water-scarce regions any conflict of interests can be solved by designing win–win scenarios. Win–win games often carry an ethical


Figure 4. The pillars of positive peace (IEP, 2018) [Colour figure can be viewed at wileyonlinelibrary.com]

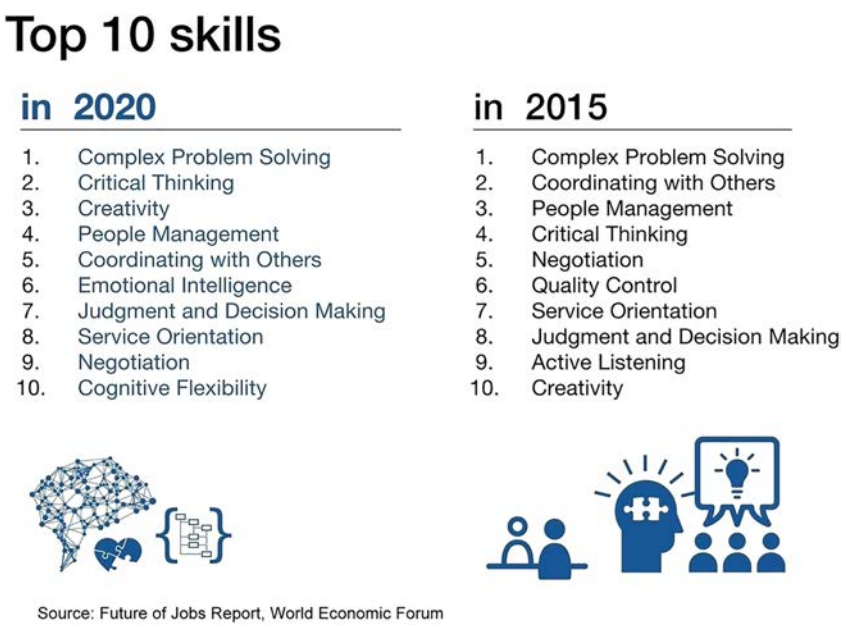


Figure 5. Top 10 job skills in 2020 versus 2015 (WEF, 2016) [Colour figure can be viewed at wileyonlinelibrary.com]

message of caring for the environment and a holistic approach to life and society. Win–win games are a powerful tool to give people self-confidence and a 'we' experience, especially when they have suffered from emotional isolation.

The independence, outside perspective and creative approach of VE teams can improve the chances of creating win–win scenarios. Creating win–win scenarios is vital when there are conflicts between development goals, environmental objectives and heritage constraints. The case study on a flood control dam in the Muko River in Japan is an example illustrating the power of creativity in solving flood control and environmental conflicts (Emami & Emami, (Inpreparation)).

- *Enthusiasm and passion for VE*. The first author has conducted some 400 VE training workshops and about 100 VE studies in large projects during the last 17 years. He believes that more than 95% of the engineers and managers who participated showed enthusiasm and passion for VE;
- *Saving cycle*. In many developing countries, there are limited resources for vital but low-cost tasks such as capacity building or IT-based schemes. If a small percentage of the savings from VE studies are used for these key tasks, the total savings can increase substantially. As an example, a tsunami warning system was proposed for the Indian Ocean before the 2004 devastating tsunami, but was rejected due to lack of funds;
- *Coping with uncertainties in water engineering*. In view of hydro systems changes, especially climate change, coping with uncertain parameters in unique water projects is a great challenge. In this context, the creativity, synergy and collected wisdom of VE teams can be rewarding.

## 3. SUMMARY AND CONCLUSIONS

Opportunities of VE for the ICID Vision 2030 are summarized as follows:

- VE can be regarded as a rigorous review;
- VE is a proven technique;
- VE has extensive applications;
- Based on thousands of studies, VE can result in unbelievable returns on investment;
- VE can play a key role in ensuring sustainable irrigated agriculture;
- VE can be used to inspire and empower the transition generation;
- VE can enhance organizational learning;
- VE methodology matches with the results of research conducted on creativity;
- VE can promote IT schemes and non-structural approaches;
- VE can be used to buttress peace by developing win–win scenarios;
- Novel ideas of a VE study can be converted to standard practice in time;

 

- VE matches closely with job skills presented by the World Economic Forum for 2020;
- VE can be the key to presenting unbiased design;
- VE can be used to devise win–win scenarios (especially when there is competition for water);
- Most people are passionate about creativity, innovation and VE;
- If saving from a VE study is properly invested (i.e. for capacity building), more savings are expected in future VE studies;
- VE has proven to be effective and efficient for coping with uncertainties in water engineering.

On the other hand, successful applications of VE are challenging, especially in developing countries with limited resources and experience. The most important prerequisites are as follows:

- appropriate laws and regulations;
- strong belief of senior managers in VE and their support;
- relatively long time needed for VE implementation;
- required human and financial resources;
- enthusiasm for VE among managers and engineers;
- win–win scenarios.

## 4. CONCLUDING REMARK

In view of the great challenges of the twenty-first century, VE can help engineers, managers and researchers take hold of the helm of the ship of history and change its course for the benefit of all humanity.

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