

# Organizational Engineering: The Emerging Stage of Industrial Engineering

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**Abstract** Industrial Engineering (IE) has experienced a remarkable development since its inception in the early years of the past century. From the perspective of the present problematic situation of the world, including people and planet, a new space of opportunities opens to IE research and professional activities. In this respect, this paper reviews the two main previous stages of IE and proposes a characterization of its emergent current stage. The resulting IE concept is an extended one, which is proposed to be identified as Organizational Engineering.

**Keywords** Organizational engineering · Industrial engineering · Sustainability

## 1 Introduction

Industrial Engineering (IE) is a sound branch of the Engineering tree whose origins are commonly agreed to be found in the analytical studies on operational tasks by Taylor (1911) in the early years of the past century. Taylor's main focus on efficiency got a remarkable backing from the assembly line experience by Henri Ford who coupled a demand objective (people's accessibility to products) with an offer objective (cost efficiency). Since that time, Industrial Engineering has been evolving by the incorporation of several intertwining lines of advancement: new theories based on observed real phenomena; new mathematical techniques applied to challenging problems; practical experiences drawn by IE practitioners; increasing

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**Table 1** Industrial Engineering Stages

	Traditional	Consolidated	Emergent
<i>Environment</i>			
Type of change	Laminar	Turbulent	Structural turbulence
Economic paradigm	Government drives	Market commands	Human development
Geo-politic paradigm	Bi-polarity	Mono-polarity	Multi-polarity
<i>INDUSTRIAL ENG.</i>			
Object of study	Manufacturing plant	Supply Networks	Sustainable Systems
Problem types	Operational	Configuration, design	Public-private design
Geographical scope	Local	International	Global
Organizational scope	Production and other	Firms network	Varied Organizations
Types of flows	Material	Information, finance	Knowledge
Actors	Firm	Network of firms	Private, public, CSOs
Decision criteria	Efficiency	Resilience	Sustainability

number of educational IE programs all over the world; diffusion of new knowledge by means of scientific conferences and reviews.

The objective of this paper is to elaborate insights on the new challenges faced by IE, reviewing its historical development.

We identify three stages in its evolution: the “traditional”, the “consolidated” and the current “emergent” stage. The contextual changes that induced this evolution are outlined in a framework (Table 1). This is next used to understand the structural changes that IE is facing nowadays and to propose the lines of adaptation required. The resulting enlarged IE concept is such a distinctive approach that we propose to rename it as Organizational Engineering.

## 2 The Industrial Engineering Concept

Industrial Engineering is presently practiced all over the world, but named according to each particular country language and traditions, such as “Génie de Gestion” in France, “Ingegneria Gestionale” in Italy, “Engenharia de Produção” in Brazil and Portugal, “Ingeniería Industrial” in Latin America, “Ingeniería de Organización” in Spain. But in every case, its concept and approach are quite similar. In various countries there are professional or academic organizations devoted to IE development, such as the Institute of Industrial Engineers (IIE) in the USA, Associação Brasileira de Engenharia de Produção (ABEPRO) in Brazil, Asociación para el Desarrollo de la Ingeniería de Organización (ADINGOR) in Spain.

The IIE (2015) official definition of IE is considered representative: “Industrial engineering is concerned with the design, improvement and installation of integrated systems of people, materials, information, equipment and energy. It draws upon specialized knowledge and skill in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems.”

Such systems are usually organizations and therefore “open systems”, which implies that interactions with their environment are crucial to understand their behavior (Lewin 1936). Consequently, IE adopts an extended vision, including in its scope the particular organization and its relations with both external organizations and people (stakeholders, transactional environment) and the rest of the environment (contextual environment). The organization dynamics is dependent on the behavior of its people subsystem. Consequently IE knowledge is drawn not only from theoretical research, but also from experience, in particular, through proactive, collaborative processes first termed “action-research” by Lewin (1946).

### 3 Traditional Approach of IE

IE is considered to have reached consistency and momentum over the period from Taylor’s time to the Second World War (WW2). Significant acquisitions in this period were: the “Gantt chart” by H.L. Gantt; the Economic Order Quantity (EOQ) by F.W. Harris; the works on motion study by F. and L. Gilbreth; the experiences on human motivation by E. Mayo. From WW2 to the 1970 decade, IE knew a steady development leading to what we consider the zenith of its traditional stage. Prominent impulse came from the inception in UK of Operational Research and its further development as Operations Research (OR) in the USA. This period raised relevant contributions such as linear programming, dynamic programming, graph theory or project programming; the incorporation of the incipient Informatics; new theories on human needs (Maslow 1943) and motivation (Herzberg 1968); the joint consideration of men and technology for the analysis of production systems by Ergonomics and the Socio-technical approach.

Considering jointly the development experienced throughout this first stage, the IE traditional approach can be characterized, in broad traits, as follows: the object of study is mainly the manufacturing plant; the geographical scope is local and the organizational scope is mainly the production function; problems studied are operational and deal with material transformation; actors concerned are usually firms looking for efficiency improvements (see Table 1, column 1).

## 4 From the Traditional to the Consolidated Stage

### 4.1 *Contextual Changes Since the Seventies*

The high growth rates of the economy in the 1960 decade (Emery and Trist 1965) led to remarkable “turbulences” in the first half of the seventies (the “oil crisis”). Huge raise in oil and raw material prices and financial costs depleted firm margins causing bankruptcy or severe financial difficulties.

This scenario required stretching responses from firms. On the one hand, from the supply side, firms had to find effective ways to reduce costs. Cost chapters such as inventory, storage space or transportation were then put into focus and the “logistic system” concept, brought from the military to the business field (Drucker 1962; Magee 1968), was applied to cut operational costs, to redesign the whole system and to redeploy vertically integrated firms as multi-firm systems, designated as supply networks in the 2000 decade. On the other hand, from the demand side, firms had to adapt to the new conditions of the competition arena, widening thus the product mix and innovating in products. Additionally, a pervading change in the business environment throughout this period was the development of the information and communication technologies, ICTs (see Table 1).

### 4.2 *Traits of the IE Consolidated Stage*

From the “oil crisis” of the 1970 decade up to the start of the great financial crisis of the last years (2008), turbulence deepened and IE was developing its “consolidated” stage, which got consistency in the years 2000–2007. Relevant facets of this development follow. In 1978 H.A. Simon was acknowledged with the Nobel Prize, representing the full recognition of the school of thought proposing a behavioral theory of the firm and decision processes based on bounded rationality. This implied the search for satisfactory alternatives instead of optimal solutions. In parallel, along the 1970 decade took place a significant debate on the appropriate focus of OR, questioning an excessive emphasis in optimization and pointing out a lack in dealing with problematic open system situations. In this respect, two papers from Ackoff (1979a, b) are fully representative. Even in the 1990 decade, the debate on OR appropriate focus stood (Corbett and van Wassenhove 1993), pointing out the gap between the managerial and the research foci. Already Simon had stated that model design had to follow two directions, either to optimize in a simplified context or to satisfy while retaining a richer set of real world properties. In this respect, the development of heuristic, simulation and multi-criteria decision techniques, powered by ICTs support, was the OR salient trait in the period, which allowed to address complex multi-actor strategic and system design problems.

Briefly, the main traits of the “IE consolidated stage” can be characterized as follows (see Table 1, column 2): the object of study is now the supply network; the

geographical scope is international; the organizational scope is a network of firms; the flows studied are not only material (now including reverse logistics), but also informational and financial; the problems addressed are not only operational, but strategic and relative to network configuration and design, involving several actors cooperating in supply networks and wishing to reach resilient solutions. The economic activities are mainly ruled by the market offer side, which tends to form oligopolies and benefit from the governmental support, in particular, by private activity deregulation. The geopolitical scenario is shaped by the USA power and its liberal politics. This stage is not disjoint from the “traditional” one. On the contrary, it incorporates the knowledge acquired along the first one, which remains available to deal with “traditional” problems.

## 5 Macro-trends in the Present Scenario

The year 2008 marked the beginning of a huge financial crisis that, initiating in the USA, extended quickly all over the world and whose consequences are presumed to still last for several years. In such scenario, the present global trends become of highest significance and require tight attention. These trends can be grouped into two sets: global structural turbulence and changes in social values.

In respect to turbulence, the financial crisis of the last years shows that its depth is, not only global, but also structural. Relevant changes in the fundamentals of our current socio-economic world are: global warming induced by human activity and deterioration of ecosystem services (Rockström et al. 2009; Schultz et al. 2013); biodiversity loses (Lenzen et al. 2012; WWF 2015); emergence of a multi-polar world; raise of BRICS and other emergent countries; surge of pro-democracy movements (Tunisia, Egypt, Libya, Syria, ...); extension of violent radical movements (Al Qaeda, Islamic State ...); interconnected global risks (WEF 2015).

In respect to social values, significant changes are spreading among people all over the world. Relevant ones are: refusal of what is perceived as corruption practices from politicians and abuse from the financial industry; refusal of extreme poverty and economic, social and political inequity; emergence of aspirations from most disfavoured people, influenced by the “western” style of living; tensions between egoistic and solidarity values; consolidation of cooperation as a global value; social consensus fragility as a consequence of perceived insufficiency of current democracy practices; increasing ecological consciousness; revision of the economic concept of prosperity (DBR 2006).

To deal with this situation, limited initiatives have been undertaken. Significant examples follow: United Nations (UN) adopted a plan for the period 2000–2015, the Millennium Objectives, addressed to mitigate the situation of the poorest in the world; the World Bank and diverse National Governments finance development projects for the disadvantaged countries; most dynamic firms have adopted a *corporate social responsibility* paradigm (MIT-BCG 2012); civil society organizations (CSOs) work for the benefit of the most disfavoured people and the environment.

Remarkably, this year 2015, a global “post-2015 Agenda”, focused on sustainability goals, is planned to be approved by United Nations (UN 2014).

## 6 Emergent Stage of IE: Organizational Engineering

Coming back to IE, some questions arise: in the present situation, what can be done by IE and how? Are there emergent opportunities for IE to contribute to the alleviation of the aforementioned problems? To answer these questions, it has to be noted that the new problems are interrelated network situations involving multiple actors, requiring appropriate “courses of action” undertaken by a coalition of different actors: people, private organizations (industrial or services firms, and others), CSOs, public bodies. In this respect, IE holds the great advantage of valuable accumulated knowledge and experience in dealing with supply networks (configuration, design, management of actor relations, knowledge transfer, etc.), which can be easily transferred to different kinds of problematic situations, constituting thus “emerging” opportunities for IE (see Table 1, column 3).

To succeed in such opportunities, five assumptions concerning the approach to be adopted by IE professionals and researchers are considered of great relevance:

- First, to play a role, not simply of problem solver in a confined situation, but one of “change agent” or “promoter”, collaborating with a variety of stakeholders on “designing and improving” roads to deal with open unsatisfactory situations, promoting thus cross-sector partnerships.
- Second, to be prepared to work in relation, not only to a variety of organization types, but also to people from diverse cultures and socio-economic contexts, being aware of the crucial importance of people perceptions and attitudes.
- Third, to extend the usual offer-side viewpoint of previous IE approaches (traditional and consolidated) to a wider focus including sustainable human needs and well-being for present and future generations. This refers not only to world’s poorest people, but also to health, education and social services for people in developing and developed countries; correspondingly, this requires reviewing and re-orientating the demand side towards sustainable consumption patterns.
- Fourth, to conceive solutions and courses of action within the constraints originated by the judicious preservation of natural resources and the correct functioning of the planet ecological systems (Rockström et al. 2009), in line with paths opened by concepts as “closed-loop supply chains”, “circular economy”, “industrial ecology” or “ecological footprint”.
- Fifth, to adopt a wider appropriate perspective (Ghoshal 2005) and become familiar with concepts, theories and methods such as: “wicked problems” (Churchman 1967; Conklin 2005); “persistent problems” (Loorbach 2009); “network society” (Castells 2000); “complex situations” (Kovacic and Sousa-Poza 2013); “transitions for sustainable development” (Loorbach 2009);

“governance for sustainable development” (Zeijl-Rozema et al. 2008); “metagovernance” (Meuleman 2008); “complex systems theory” (Midgley 2003); “embedded case studies” (Scholz and Tietje 2002); “cognitive mapping” (Kitchin 1994); “sense making” (Weick 1995); “consensus building processes” (Innes and Booher 1999); “problem structuring methods” (Kato 2011).

We propose to refer to this IE “emerging” stage as Organizational Engineering. This stage, including the above-mentioned five assumptions, is not considered to be disjoint from the previous ones, but a deeper and extended stage containing the precedent ones. The resulting Organizational Engineering (OE) concept constitutes an emerging paradigm for IE that deserves to be clearly identified. The term “organizational” in the OE wording highlights thus the focus of this approach on designing and improving interlinked organizations devoted to cope with complex, real-world problematic situations.

## 7 Conclusions

Industrial Engineering (IE), since its inception in the early years of the past century, has developed a sound trajectory, having reached two significant stages that we characterize as the “traditional” and the “consolidated” ones. Since the 2008 financial crises, the world context is changing rapidly, which implies that a new perspective deserves to be adopted by IE in order to preserve its usefulness for coping with the new problematic situations. In this respect, this paper tries to contribute to the corresponding reflection proposing an “emergent” approach for IE.

The 2050 planet scenario seems incompatible with a global extension of the current model of living standardized in the developed countries. In order to preserve planet sustainability and a peaceful mankind, a transition towards a new societal model is necessary. This requires world governance and organizations working for the benefit, not only of customers able to pay, but of the entire world population. As a consequence, more complex organizational configurations and goals are needed, which represent emerging opportunities for IE, but require an appropriate vision.

The resulting IE concept is a new, deeper and extended one, which is proposed to be identified as Organizational Engineering.

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