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RESEARCH PAPER

Fit Gap Analysis in ERP Implementation: A Novel Management Science Approach

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Abstract

This paper addresses the critical challenge of improving success rates in enterprise resource planning (ERP) implementation by introducing a novel management science approach that replaces the commonly used judgment-based and qualitative methods in fit-gap analysis. Traditional methods are often employed due to the significant confidentiality surrounding ERP vendors and the limited availability of data and procedures, which restricts management scientists' contributions as effectively as they do in other fields. To overcome these limitations, this study develops two alternative methods: a bi-objective optimization model and a game-theoretic model, specifically tailored to the information system platforms of target organizations. These innovative methods take into account several critical factors, including organizational legacy structure, resource availability, budget constraints, and two competitive strategies: ERP software customization and organizational redesign. By addressing the competitive and cooperative dynamics inherent in ERP implementation, this research aims to provide a more systematic and quantitative framework for decision-making. The effectiveness of this quantitative approach is illustrated through a comprehensive industry case study, demonstrating its practical applicability and potential to enhance ERP implementation success rates.

Keywords: ERP Implementation, Fit-Gap Analysis, Organizational Redesign, Cournet Game, Management Science.

Introduction

For several decades, numerous enterprises across various sectors—including manufacturing and production systems, the service industry and supply chain networks (SCNs)—have implemented costly enterprise resource planning (ERP) systems. These systems are designed to help businesses adapt to the constantly evolving market environment, manage complex organizational functions, improve quality, reduce costs, and increase efficiency to remain competitive on a global scale (Oldacre 2016; Imane et al. 2022; Subbarao et al. 2023).

An ERP system is a software solution enabling organizations to unify, automate, and integrate an organisation's data and business processes, track workers, processes, machinery, customers, applications, warehouses, production plans, accounting and financial records, databases, and transportation across the enterprise in near real-time (Yap 1999; Buxman & Konig 2000; Kumar & Van Hillsgersberg 2000; Irani & Love 2001; Chen 2003; Sumner 2005;

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Keong et al. 2012; Kanellou & Spathis 2013; Parthasarathy & Sharma 2014; Bahssas et al. 2015; Madanhire & Mbohwa 2016; Chaveesuk & Hongsuwan, 2017; Haddara 2018; Sigala et al. 2020; Grandón et al. 2021; Alsharari 2022; Lahlou et al. 2022; Tayyab & Ahmad 2023; Roberts et al., 2023; Subbarao et al., 2023Gessa et al. 2023).

ERP software solutions consist of various modules, each a set of stand-alone software components that perform specific functions, namely financial accounting, production planning, purchasing, inventory control, sales and distribution, and human resources as core modules (Stephan 2001; Murphy and Simon, 2002; Shang and Seddon 2002; Zhang 2005; Fan and Fang, 2006; Muscatello and Chen 2008; Yang and Su 2009; Perera and Costa 2008; Dezdar and Ainin 2011; Annamalai and Ramayah 2011; Beal 2015; Siddiqui et al. 2021; Alsharari 2022).

ERP systems are integral to modern business practices, providing organizations with the tools necessary to integrate and streamline their operations. These systems enhance operational efficiency (Amalnick et al., 2010) by automating routine tasks, thereby reducing manual effort and minimizing errors (Alsharari, 2022). By centralizing data from various departments into a single platform, ERP systems facilitate better data analysis and reporting, enabling informed decision-making (Sumner, 2005).

Moreover, ERP systems improve collaboration across departments by providing real-time access to information, fostering a more cohesive work environment (Zhang, 2005). Their scalability and flexibility allow organizations to adapt to changing market conditions and accommodate growth, making them suitable for businesses of all sizes (Buxmann & König, 2000). Additionally, ERP systems assist organizations in maintaining regulatory compliance by providing tools for tracking and reporting necessary data, thereby reducing the risk of noncompliance (Irani & Love, 2001).

Generally, by enhancing access to information, ERP systems enable organizations to respond more quickly to customer inquiries and needs, leading to improved customer satisfaction and loyalty (Sigala & Christou, 2020). In summary, ERP systems are vital for organizations seeking to enhance efficiency, improve collaboration, and maintain a competitive edge in today's dynamic business environment.

Despite these benefits, many organizations still encounter significant challenges, including severe schedule delays, additional costs, quality issues, and even total failures. In a report by Branka in TRUELIST, a Deloitte study found that while some businesses can meet or exceed their goals, ERP implementations frequently fail, with failure rates ranging from 55% to 75% (Branka, 2023). See also (Guimares et al. 1995; Hong & Kim, 2002; Elragal & Haddara 2013; Hajj 2019) for further reports on ERP failures.

Table 1. Major causes of failure in ERP implementations

Causes of failure	References
There is always a gap, or misfit, between an ERP system's business processes and those of the implementing organization.	Parthasarathy and Sharma, 2016
The challenge of rethinking organizational structure.	Nizamani et al. 2017
Change to "Difficulty in customizing to fit the target organization.	Abugabah and Sanzogni 2009; Khan 2019;
The challenging choice between organizational redesign (the so-called Vanilla method), ERP software redesign, or customizing the ERP package to fit current business processes.	Lou and Strong 2004; Parthasarathy and Sharma 2014 and 2016; Imane et al. 2022; Van Beijsterveld & Van Groenendaal 2016; Ancveire 2018;
The degree to which the ERP software structure and culture align with the organizational structure and legacy culture.	Markus & Robey, 1983, 1988, Soh, Sia, & Boh, 2003, Morton and Hu, 2008;
significant pressures imposed on decision-making processes, management style, employees, and business partners, leading to substantial resistance and underperformance.	Pawlowski et al. 1999; Wood & Caldas 2001; Yin Yeh & Ou; Yang 2010

Resistance by IT departments due to the department's reliance on an established legacy system and the required retraining hurdles.	Gowigati & Grenier 2001; Yin Yeh & OuYang 2010; Puranam 2012; San Cristóbal 2015;
ERP implementation causes changes that often lead to internal conflicts, such as shifts in hierarchy, changes in the level of centralization, and alterations in the span of control.	Gavidia 2016; Van de Ven et al. 2013; Puranam 2018; Bhaskar 2020
Always there is a gap, or misfit, between an ERP system's business processes and those of the implementing organization.	Wieder et al. 2006; Štemberger and Kovačič 2010; Seddon et al. 2010; Parthasarathy and Sharma, 2016; Çakmak 2016; Abu Ghazaleh et al. 2019;

To address the prevalent challenges associated with qualitative and judgmental methodologies in various industries, which often have led to higher failure rates in ERP implementation, this paper establishes a rather quantitative and managemental science-based framework for optimal decision making by employing a bi-objective optimization model and a game model.

The remaining sections of the paper are organized as follows. In Section 2, a brief literature review is presented. A bi-objective optimization model is presented in Section 3. In Section 4, a game model is developed, and in Section 5 an industrial case study is worked out to check the working logic and the effectiveness of the models. In Section 6, the paper is concluded discussing the novel features of the proposed model and future directions for further research.

Literature Review

Successful ERP implementation relies on several critical success factors. These include, namely, a clear project strategy, defined objectives, stakeholder engagement, effective change management, comprehensive training, manageable project scope, and adequate resources and fit-gap analysis. Focusing on these elements can significantly enhance the likelihood of achieving desired outcomes (Al-Mashari& Zairi, 2000; Burch & Gibbons, 2013; Sadegh Amalnick et al., 2010; Fenwick, 2016; Zhang et al., 2003).

Fit-gap analysis is indeed considered a critical success factor in ERP implementation, as it helps identify the alignment between business processes and the ERP system's capabilities. This analysis ensures that the system meets organizational needs and minimizes disruptions during implementation (Fenwick, 2016).

There are always gaps, or misfits, between an ERP system and the requirements of an organization, which can have various consequences at the strategic, tactical, and operational levels, misfit analysis becomes a central challenge in successful implementation of ERPs.

Each ERP implementation project consists of certain phases, which are important milestones to be met for a successful run. They are: 1) Pre-implementation (discovery), 2) Vendor selection, 3) Planning and preparation, 4) Customization and configuration, 5) Testing, 6) Training and change management, 7) Go-live, and 8) Post-implementation phase. Throughout these phases, management science offers a wide range of methods that could replace the predominantly qualitative and judgmental approaches currently in use. However, management science approaches have hardly been used due to surrounding confidentiality existing in this market.

Among the management science approaches, the optimization model stands out for its ability to address the cooperative aspects of misfit analysis, while the non-cooperative game model is particularly effective in handling the competitive dynamics of misfit analysis within an organization.

In Grabis (2019), a pioneering optimization model was developed for fit-gap analysis. An optimal gaps resolution strategy using the vendor's software evolution roadmap was proposed.

This optimization model, however, deals only with our first strategy, i.e., the ERP customization (software redesign) strategy. Also, Çakıret al. (2022) applied an integer linear programming model to schedule the ERP software project implementation plan as well as its cost levelling.

Non-cooperative game theory is a mathematical framework involving different players (agents or decision-makers). It deals with situations in which competition occurs at both individual and group levels, whether simultaneous or sequential, with both complete and incomplete information considered among rational players along with their preferences (von Neumann & Morgenstern 1944; Nash 1951; Debreu 1952; Aumann 1987; Kim 2014; Mustata et al. 2017; Tengiz 2020). Since the early 1940s game theory has found applications in areas such as economics, engineering design, biology, business, management, labor arbitration, supply chains, and others (Leng and Parnar, 2005; Sartipi 2020; Peng, 2021).

Non-cooperative game theory studies the likelihood of outcomes and behaviors of players who prioritize their own objectives and achievements. These players do not have the opportunity or desire to plan as a group in advance or communicate to coordinate their actions. See also Generalized Nash Equilibrium games (GNE) (Lemaire 1991; Osborne & Rubinstein 1994; Binmore 2007; Facchinei & Kanzow 2010; Dreves et al. 2011). The fundamental solution concept in non-cooperative games is called the Nash equilibrium solution, which is different from an optimal solution though in some cases two concepts coincided (Monfared et al. 2020; Monfared et al. 2021; Mahdipour Azar et al. 2021).

Some researchers have considered non-cooperative game theory to tackle aspects of the ERP implementations. Among them, Yakhneeva et al. (2020) developed a two-player game model for software development in which interactions existed between the software producer and the consumer. See Table 2 for a brief summary of the relevant works. Skatkov & Shevchenko (2016) developed a competitive game model as a management model for ensuring guaranteed levels of IT service in ERP. To do so various technologies for processing information flow and restructuring IT services are modelled as a game problem in which the ERP system and IT services support system act as opponent players.

Another leading work which is helpful within the management science approach is by Donaldson (2001) who developed a novel organizational fit-gap contingency analysis framework demonstrating that the organizational efficacy is achieved only by conforming organizational characteristics to contingencies. Contingency is here defined as any variable that adjusts the effect of an organizational characteristic on organizational performance. The main organizational contingencies according to Donaldson are 1) specialization, 2) formalization, 3) structural differentiation, and 4) decentralization. Later Morton and Hu (2008) followed Donaldson's work and Mintzburg's (1979) work to propose an improved framework for fit-gap contingency analysis. In that framework, six different types of idealized organization structures were defined, in which specialization and formalization was merged, as are detailed in Table 2.

Table 2. Morton and Hu's work on contingency fit modelling

No.	Organizational type	Structural dimensions			Degree of fit and likelihood of ERP success
		Formalization	Structural differentiation	Decentralization	
1	Machine bureaucracy	High	Medium	Low	High
2	Professional bureaucracy	Low	High	High	Low
3	Professional bureaucracy support staff component	Low	Medium	Low	High
4	Divisionalized form	Medium	High	High	Low
5	Adhocracy	Low	High	High	Low
6	Administrative adhocracy operating component	High	Medium	Low	High

Note that that formalization here is defined as the standardization of work processes and documentation (Donaldson, 2001). Specialization within an organization is about the extent that jobs are carefully defined in terms of essential knowledge, skill and experience (Green, et al., 2005); Structural differentiation is defined as the difference in goal orientation and in the formality of the structure of the organizational units (Lawrence & Lorsch, 1967; Morton, 2008). Decentralization is defined as the extent to which power over decision-making in the organization is dispersed among its members (Mintzberg, 1980; Morton, 2008).

Table 3. Summary of literature review

No	Authors	Year	Focus/Objective	Key Findings	Relevance to Topic
1	Buxmann & König	2000	Role of ERP systems in developing flexible organizations.	Identified how ERP systems contribute to organizational flexibility and responsiveness.	Supports the need for adaptable strategies in ERP implementation.
2	Donaldson	2001	Introduction of a contingency analysis framework for organizational fit-gap.	Emphasized the alignment of organizational characteristics with contingencies for efficacy.	Provides insights into organizational factors affecting ERP success.
3	Irani & Love	2001	Influence of knowledge on ERP system success.	Highlighted the importance of knowledge management in successful ERP implementations.	Emphasizes the role of knowledge in overcoming implementation challenges.
4	Sumner	2005	Overview of ERP systems and their impact on business processes.	Discussed the role of ERP in integrating business processes and improving decision-making.	Provides context for the necessity of effective ERP implementation strategies.
5	Leng & Parnar	2005	Applications of game theory in various fields.	Reviewed the applications of game theory in economics, engineering, and management.	Provides a theoretical basis for applying game theory to ERP implementation challenges.
6	Morton & Hu	2008	Improvement of fit-gap contingency analysis framework.	Defined six idealized organizational structures and their impact on ERP success.	Offers a structured approach to understanding organizational fit in ERP implementations.
7	Skatkov & Shevchenko	2016	Creation of a competitive game model for IT service management in ERP.	Modeled IT service levels as a game problem, ensuring guaranteed service levels.	Illustrates how game theory can enhance service management in ERP systems.
8	Osnes et al.	2018	Literature review on ERP implementation strategies from 2000 to 2017.	Identified gaps in existing research on ERP implementation success factors.	Serves as a basis for proposing a novel framework for ERP implementation.
9	Grabis	2019	Development of an optimization model for fit-gap analysis in ERP systems.	Proposed an optimal gap resolution strategy using the vendor's software evolution roadmap.	Provides a foundation for optimization approaches in ERP implementation.
10	Yakhneeva et al.	2020	Development of a two-player game model for software development interactions.	Analyzed interactions between software producers and consumers using game theory.	Demonstrates the applicability of game theory in ERP-related decision-making.
11	Tengiz	2020	Application of non-	Explored competitive	Supports the integration of

			cooperative game theory in ERP implementation.	dynamics in ERP projects using game theory principles.	game theory in enhancing ERP implementation strategies.
12	Sigala & Christou	2020	Role of ERP systems in enhancing customer service.	Demonstrated that ERP systems improve customer service through better data access.	Connects ERP success to customer satisfaction, reinforcing the need for effective implementation.
13	Monfared et al.	2020	Examination of Nash equilibrium in non-cooperative games.	Discussed the implications of Nash equilibrium for decision-making in competitive environments.	Relevant for understanding competitive dynamics in ERP implementation.
14	Mahdipour Azar et al.	2021	Analysis of game theory applications in supply chain management.	Explored how game theory can optimize supply chain decisions and collaborations.	Suggests potential applications of game theory in ERP-related supply chain contexts.
15	Peng	2021	Game theory applications in business management.	Investigated the use of game theory to enhance strategic decision-making in businesses.	Supports the integration of game theory into ERP implementation strategies.
16	Çakıret al.	2022	Application of integer linear programming for ERP project scheduling.	Developed a model for scheduling ERP implementation and cost leveling.	Highlights the use of optimization techniques in improving ERP project management.
17	Alsharari	2022	Impact of ERP systems on operational efficiency.	Found that ERP systems significantly enhance operational efficiency and data accuracy.	Highlights the importance of efficiency in successful ERP implementation.
Current Study*	Gharegozlou & Monfared	2024	A mathematical approach for ERP gap resolution using Game theory by considering organizational ideal type	Proposing a mathematical model to increase ERP implementation success rate through optimal misfit resolution strategy	Applying game theory as well as considering organization ideal type to find the optimal strategy to cover identified gaps so that ERP success likelihood increases

Despite the widespread adoption of ERP systems, successful implementation remains a significant challenge due to the persistent gaps or misfits between the ERP system and organizational requirements. These misfits can have strategic, tactical, and operational consequences, making misfit analysis a central challenge in ERP success (Grabis, 2019).

The literature reveals a scarcity of studies employing theoretical frameworks, such as game theory or optimization, to address ERP implementation challenges. Furthermore, there is a lack of focus on gap resolution strategies resulting from fit-gap analysis. This gap in the literature motivates the proposal of a novel gap resolution framework for ERP implementation, utilizing a bi-objective optimization model and a game model, inspired by the findings of Osnes et al. (2018).

As reviewed so far, only a few studies have employed theoretical perspectives, such as game theory or optimization, to address ERP implementations, and even fewer have focused on gap resolution strategies resulting from fit-gap analysis. Inspired by Osnes et al. (2018), who have conducted a literature review spanning from 2000 to 2017, we propose a novel gap resolution framework for ERP implementation using a bi-objective optimization model and a game model.

Mathematical Preliminaries

Here, in this Section the basic assumptions, notations, and decision variables used in both the bi-objective optimization and game model are introduced.

The Basic Assumptions

(1) Gaps are assumed to be equally weighted in terms of getting covered.
(2) Gaps are independent.
(3) There is no inter-dependency in customizations in case gaps are optimally selected to be covered by ERP customizations.
(4) Only one strategy, either ERP redesign (software customization) or organization redesign, can be adopted to covering a certain gap. Though, different gaps can be covered with different strategies.
(5) To improve an ERP success rate, i.e., with higher likelihood of success, the current organization structure may improve to a better situation according to only one of the ideal types in Table 2. For example, if in an enterprise the current status of formalization is low, it can only be enhanced to either medium status or high status, or if the current structural differentiation is in low/high status, it can only be rectified to medium status so that organizational structure will become more compatible to the organizational ideal type in Table 2 to enhance the possibility of ERP success rate. The same is true if decentralization is now at the high status, it can only be amended to either medium or low status, again enhancing the success rate.
(6) In case a change in organizational structure is needed to cover a gap, such change can be considered in formalization, or structural differentiation, or decentralization or in a combination of any of these dimensions. For example, 3 gaps may get covered/resolved by 3 different organizational changes, e.g., one gap by formalization, one gap with differentiation, and one with decentralization, independently.
(7) To improve an organizational structure, only one change can take place within any given planning horizon, i.e., in order to achieve a better ideal type in its structural dimensions. For example, if the formalization of an enterprise is now high, it cannot change to a lower status of medium or low, or if decentralization is now at medium status, it cannot change to a high status, i.e., it can remain medium or improve to a low status.
(8) For all gaps both ERP redesign (customization) and organization redesign strategies are applicable at different costs and impacts.

It should be noted that from 7 assumptions made above assumption number 2, 3 and 4 are taken from Grabis (2019). Other assumptions, which plays a significant role in turning a currently judgmental-qualitative decision model into a quantitative and rational decision model are based on the first author’s own experiences in dealing with some real-world case studies during last 15 years.

Notations

i:	Identified gaps index by fit-gap contingency analysis, i.e., 1, 2…,G_T
j:	index of players or subsidiaries within the parent organization, i.e., 1, 2,…, E
m:	~~Parent~~ organization current status (see Table 2)
n:	~~Parent~~ organization improved status
M:	Set of possible states in a parent organization based on each structure dimensions of ideal type including {high (1), medium (2), low (3)}, i.e., degree of formalization, structural differentiation and decentralization.

Decision Variables

S_j:	Total number of gaps that could be covered for player or subsidiary *j;*
$S^{ERP}{}_{i,j}$:	If gap *i* can be covered by ERP redesign 1, else 0 (for player or subsidiary *j*);
$S^{ORG}{}_{i,j}$:	If gap *i* can be covered by organization redesign 1, else 0 (for player or subsidiary *j*);
$R^{Form}_{m,n,j}$:	If formalization in organization moves from m to n then is 1, else 0 (for player or subsidiary *j*);
$R^{Diff}_{m,n,j}$:	If structural differentiation in organization moves from m to n then is 1, else 0 (for player or subsidiary *j*);
$R^{Dec}_{m,n,j}$:	If decentralization in organization moves from m to n then is 1, else 0 (for player or subsidiary *j*);

Parameters

C:	Average cost of covering a gap regardless of the strategy adopted and who the player is;
P:	Penalty of not covering a gap regardless of the strategy adopted and who the player is;
r:	Average human resources required to cover a gap regardless of the strategy adopted and who the player is;
C_i:	Effort/cost needed to cover/resolve gap *i* through ERP redesign (customization);
C'_i:	Effort/cost needed to cover/resolve gap *i* through using ERP standard features
$C_{mn,j}$:	Effort/cost of moving organization formalization from situation *m* to *n* for player *j;*
$C'_{mn,j}$:	Effort/cost of moving organization structural differentiation from situation *m* to *n* for player *j;*
$C''_{mn,j}$:	Effort/cost of moving organization decentralization from situation *m* to *n* for player *j*;
R:	Available resources in implementation period based on man-hour (the effort one manpower needs to put per hour);
G_T:	Total number of gaps identified through fit-gap contingency analysis, which are planned to be covered/resolved;
g_j:	Total gaps for player *j*;
Pi	*Resource required (man-hours) to cover gap i with ERP redesign (customization)*
P'i	*Resource required 9man-hours) to cover gap i with organization redesign*
$L(S_j)$:	Penalty incurred to the parent organization if a gap of player *j* does not get covered which is a function of number of un-covered gaps;
B_T:	Total budget available for running ERP;

Game Model

In the game model, given the limited resources and budget often assigned to ERP implementation projects and the need to minimize failure risk, each player within the organization competes to cover as many gaps as possible with minimal changes to their current processes. This creates a non-cooperative Cournot game among the players (Esmaeili et al. 2009; Esmaeili et al. 2016; Zare et al. 2017; Zare et al. 2019), where the penalty cost of not covering a gap is a function of the number of uncovered gaps.

The Cournot game is a fundamental economic model that assumes a market with two firms producing the same (homogeneous) product. In our context, players act similarly by competing to cover gaps in the ERP implementation process, balancing their resources and minimizing penalties.

In this market, the decisions involve the quantities produced by both firms to meet market demand. The quantity produced by each firm is denoted by qi (i = 1, 2) (Shapiro, 1989; Osborne & Rubinstein 1994; Askar et al., 2016). Also, the production cost is assumed linear, $C(q_i) = cq_i$, where $c \geq 0$ is a marginal cost, meaning that the per-unit-cost is equal for both firms. The consumer demand Q for the product at price p is denoted by F(p); the inverse of F is written f which is formed as p= a - bQ and the market-clearing price is given by p= f(Q), where $Q=q_1+q_2$ and q_i is the amount supplied by firm i. with this in mind, profit function can be formulated as shown below (Barr & Saraceno, 2005): $\Pi_1(Q) = p(Q)q_1 - cq_1$ for firm 1, and $\Pi_2(Q) = p(Q)q_2 - cq_2$ for firm 2. Now, as firms are assumed to be profit-maximizers, the first-order conditions for each firm are as below:

$$\frac{\partial \Pi_1\,(q_1\,,q_2\,)}{\partial q_1} = a - 2bq_1\, - bq_2 - c = 0\; \rightarrow\; q_1\; = \frac{a-c}{2b} - \frac{q_2}{2}$$
$$\frac{\partial \Pi_2\,(q_1\,,q_2\,)}{\partial q_2} = a - 2bq_2\, - bq_1 - c = 0 \rightarrow\; q_2\; = \frac{a-c}{2b} - \frac{q_1}{2}$$

These two equations describe each firm's optimal quantity of given the price firms face in the market, p, the marginal cost, c, and quantity of rival firms and they can be as a firm's "Best Response" to the other firm's level of production. Considering the symmetrical relationship between firms the equilibrium quantity can be obtained by letting q1=q2=q* that assures in the equilibrium levels none of the firms tends to change their production level as doing so will harm the firm at the benefit of their rival.

The production quantity in equilibrium is then $q^* = \frac{a-c}{3b}$. Hence, the Nash equilibrium solution is obtained. In the Cournot duopoly game model, we formulate the competition between players which are different subsidiary entities in a parent organization to determine number of gaps that can be covered by each player. It should be mentioned, having the limited resources and budget, the dependency of cost of penalty to number uncovered gaps and the simultaneous and independent decision making of each player on gap resolution were the trigger to consider Cournot game here in which gaps serve as the quantity of each firm (player) in the so-called production model of Cournot duopoly game. Here, in our model the penalty cost serves as the price in Cournot model, which is a function of number of gaps to be covered and the players compete with each other within the holding company, i.e., the parent organization in order to minimize the penalty cost, i.e., the so-called production level in Cournot duopoly model.

The objective function or the utility function of the Cournot duopoly model consists of minimizing the penalty of the gaps not getting covered: $Min\ \mathrm{Z} = \ \mathrm{L}(S_j) * (G_T - \sum_j S_j)$. As the penalty of not covering a gap is an inversion of function of number of uncovered gaps, we can rewrite the $\mathrm{L}(S_j)$ and G_T as: $\mathrm{L}(S_j) = \ A - b * (\sum_j S_j)$ and $\sum_j g_j = G_T$ where A and b are the inverse demand function parameters leveraging the Cournot game model. Also, the last equation shows that the total gaps identified for the parent organization is the same as the sum of the gaps identified for each player or subsidiary companies (j=1, 2,.., E). Hence the Cournet game model becomes: $Min\ \mathrm{Z} = \ (A - b * (\sum_j S_j)) * (G_T - \sum_j S_j)$ s.t. $r\ .\ (\sum_j S_j) \leq R$, $\sum_j S_j \leq g_j$, $\mathrm{C}\,.\,(\sum_j S_j) \leq \mathrm{B}_T$, $S_j \geq 0$. The first equation is the objective function for minimizing the penalty cost in terms of gaps not getting covered. The second equation is the resource constraint which is the average resource required for each gap to get covered. The third equation defines those total covered gaps of any player cannot be more than the total number of gaps identified in fit-gap analysis for that player. The next equation is the budget constraint in terms of average cost required to cover each gap for player j. Now, when the optimized number of gaps to be covered for each player in Cournot duopoly competition game was determined.

A Bi-Objective Optimization Model

Here, the aim is to model the misfit contingencies dilemma by considering cost and penalty in a bi-objective model. The model incorporates organizational redesign as well as software redesign (or customization) strategies by considering both the organizational type and its structural dimensions. We utilize six types of organizational structures as identified by Mintzberg (1980) and Morton and Hu (2008). Specifically, Morton and Hu’s framework, depicted in Table 1, helps identify optimized strategies for gap resolution in real-world situations affecting each entity within an organization. Here, we consider the basic assumptions behind our bi-objective optimization model.

$$Min\ Z_1 = \sum_{n\leq m}(C_{mn}\,.R^{Form}_{m,n} + C'_{mn}\,.R^{Diff}_{m,n} + C''_{mn}\,.R^{Dec}_{m,n}) + \sum_{i=1}^{G_T} C'_i.\sum_{j} S^{ORG}_{i,j} + \sum_{i=1}^{G_T} C_i.\sum_{j} S^{ERP}_{i,j} \quad (1)$$

$$Min\ Z_2 = \sum_{j=1}^{E} L(S_j).(1 - \sum_{i=1}^{G_T}(S^{ORG}_{i,j} + S^{ERP}_{i,j})) \quad (2)$$

$subject\ to$:

$$\sum_{i=1}^{G_T} P_i\ .S^{ERP}_{i,j} + \sum_{i=1}^{G_T} P'_i\ .S^{ORG}_{i,j} \leq R \qquad \forall\, j = 1,..,E \quad (3)$$

$$\sum_{n\leq m,j}(C_{m,n,j}\,.R^{Form}_{m,n,j} + C'_{m,n,j}\,.R^{Diff}_{m,n,j} + C''_{m,n,j}\,.R^{Dec}_{m,n,j}) + \sum_{i=1}^{g_j} C'_i.\sum_{j=1}^{E} S^{ORG}_{i,j} + \sum_{i=1}^{g_j} C_i.\sum_{j=1}^{E} S^{ERP}_{i,j} \leq B_T \quad (4)$$

$$S^{ERP}_{i,j} + S^{ORG}_{i,j} \leq 1 \qquad \forall\, i = 1,..,g_j; \forall\, j = 1,..,E \quad (5)$$

$$\sum_m \sum_n R^{Form}_{m,n,j} \leq 1 \qquad \forall\, n,m \in M; \forall\, j = 1,..,E \quad (6)$$

$$\sum_m \sum_n R^{Diff}_{m,n,j} \leq 1 \qquad \forall\, n,m \in M; \forall\, j = 1,..,E \quad (7)$$

$$\sum_m \sum_n R^{Dec}_{m,n,j} \leq 1 \qquad \forall\, n,m \in M; \forall\, j = 1,..,E \quad (8)$$

$$S^{ORG}_{i,j} \leq R^{Form}_{m,n,j} + R^{Diff}_{m,n,j} + R^{Dec}_{m,n,j} \leq 3 * S^{ORG}_{i,j} \qquad \forall\, n,m \in M; \forall\, i = 1,..,g_j;\ \forall\, j = 1,..,E \quad (9)$$

$$\sum_{i=1}^{g_j} S^{ORG}_{i,j} + S^{ORG}_{i,j} = S_j \qquad \forall\, i \in g_j; \forall\, j = 1,..,E \quad (10)$$

$$R^{Form}_{m,n,j}, R^{Diff}_{m,n,j}, R^{Dec}_{m,n,j}, S^{ERP}_{i,j}, S^{ORG}_{i,j} \in \{0,1\} \quad (11)$$

Here is our proposed bi-objective optimization model handling gap resolutions in an ERP:

Equation (1) is our first objective function, which seeks to minimize the cost of covering gap i through organizational redesign (standard features), or ERP redesign (customization). Equation (2) is our second objective function minimizing the penalty for not covering a gap. It should be noted that taking the cost equation (1) as the only objective function results in a single-objective optimization model, which, while simpler, is inappropriate. The penalty function of equation (2) can represent many important metrics, such as lost sales, increases in operational costs due to incorrect costs of goods sold (COGS), payroll, overhead costs, maintenance costs, retention losses for delayed delivery due to incorrect estimations in lead time, transit time, delivery time, backorders, overselling, and penalties due to inappropriate financial tax and insurance reports. Based on expert views, these penalties can amount to almost 10% of annual revenue or even more. All the factors of concern in our second objective function may appear to be transferrable into cost measures and incorporated into the first objective function. However, this approach compromises the duality of cost and penalty, which are currently modelled as conflicting objective functions within a bi-objective model to reflect the intricate nature of gap resolutions. Consequently, while the first objective function solely seeks to minimize the cost of gap resolution, it may not fully encapsulate the significance and repercussions of leaving a gap unaddressed, see also (Wu et al., 2007, Yen et al., 2011).

Constraint (3) limits the available resources that can be assigned to resolve identified gaps through either ERP redesign, or organizational redesign. Constraint (4) sets the budget limit for the ERP implementation project to cover identified gaps for each subsidiary company. Constraint (5) ensures that a gap is resolved using only one strategy, either ERP redesign or organizational redesign, not both. Constraints (6), (7), and (8) restrict organizational redesign to move to only one improved structural status in formalization, structural differentiation, and decentralization, respectively. For example, formalization can only improve from a medium level to a high level. Constraint (10) limits the number of gaps to be covered by each available strategy for a subsidiary to not exceed the total number of gaps identified in the first stage. Constraint (11) defines the characteristics of the decision variables in the model. These constraints help to structure the decision-making process for ERP implementation, balancing resource allocation, budget limitations, and organizational changes within the model's framework.

Notice that our proposed model is different from Grabis (2019) model in different aspects including 1) building a bi-objective optimization model for gap resolution by considering the gap resolution costs, and not-covering-gap penalty as two important rational and effective objective functions, 2) gap covering by two competing strategies of ERP redesign and organizational redesign, i.e., very helpful now with real-world cases, and 3) taking organization ideal types and organizational structure dimensions into the logic of gap resolution (see Table 2).

The Case of ERP Implementation in an International Holding

An international holding company called Alfa operates in the area of manufacturing is considered here. The holding company, i.e., the parent organization, recently decided to upgrade its information system platform by adopting and implementing one of the world's leading ERP systems called SAP. Alfa acquired two different subsidiary companies, Beta and Gamma, which were formerly independent manufacturing firms in the same industry (the actual names are not disclosed due to confidentiality and business constraints).

- In the first phase of implementation, a fit-gap analysis was conducted by experts in the company through numerous meetings. This analysis identified a total of 303 gaps, with 165 gaps assigned to company Beta and 138 gaps assigned to company Gamma through the Cournet duopoly game. Due to business concerns, detailed information about these gaps cannot be disclosed. However, four examples are explained below:
- Customizing the "customer approval date" as the invoice posting date, which is not handled currently in the standard SAP-ERP system. This required customization featured gap is applicable for both subsidiary companies, Beta and Gamma.
- For a comprehensive "open sales order", which has not been delivered to customer yet, a comprehensive report is needed to be developed according to business requirements. This featured gap is also applicable for both subsidiary companies, Beta and Gamma.
- Customer is running a "consignment process" as a final sale since the legacy system is not able to cover the consignment process. While considering the SAP standard functionality to meet the requirement, this process has been changed in the organization and adapted the standard SAP. This effected different departments including sales, supply chain, logistic and finance and got approved by all. This added featured gap is only applicable to company Gamma, while as part of harmonization both companies may need to use the same process.
- Selling products from another "subsidiary's inventory" was getting handled as a full purchase now and as such leading to many redundant documents taking more time to process the customer need, hence SAP cross selling process is proposed as a standard functionality to reduce system load as well as workforces' resulting in a more agile demand fulfilment, shorter lead-time, less inventory keeping cost as well as transit time. This featured gap only applies to company Beta.

It is worth noting that the first phase of gap contingency analysis remains primarily a judgmental and qualitative approach currently practiced across various industries. Our proposed game and bi-objective optimization models are developed to replace the second phase of strategy identification, which is often challenging due to conflicts and controversies. Naturally, all identified gaps in the two subsidiary companies, Beta and Gamma, cannot be addressed due to limited budget and expertise resources. Therefore, gaps of significant importance and impact need to be prioritized.

The competition between Beta and Gamma was modelled by a Cournot duopoly model, with each subsidiary striving to cover more of its own gaps and exerting pressure on the parent company, Alfa. The model parameters are R (man-hours) =35’000, B_T (\$) =100’000, C_B (\$) =360, C_G (\$) =320, r_B (man-hours) = 150, r_G (man-hours) = 140, A=300, and b=0.714.

Hence, the Cournot duopoly game model will become: $Min\ \mathrm{Z} = \big(300 - 0.714\,(S_B + S_G)\big) * (303 - \boldsymbol{S_B} - S_G)$ s.t.: $150S_B + 140S_G \leq 35'000,\ \ S_B \leq 165,\ \ S_G \leq 138,\ \ 250\,S_B + 300\,S_G\ \leq 100'000, S_B, S_C \geq 0.$

The model is solved as a mixed integer non-linear programming model in GAMS Release 24.7.3 obtaining the results of S_B = 125, S_G= 125, total penalty of 11169.8 \$ and total cost of 88120 \$ at the level of holding company Alfa.

Now, by realizing the Nash equilibrium solution for S_B and S_G, we may perform the bi-objective optimization model to find out how each gap can best be resolved in each subsidiary company Beta and Gamma, accordingly. Solving the bi-objective optimization model for player Beta will result in cost, penalty and gap resolution strategy as shown in Table 4.

Table 4. Results of the optimization model for subsidiary company Beta with 165 gaps

S^{ORG} (Gap IDs by Organization redesign)	**S^{ERP} (Gap IDs by ERP Redesign)**
4, 6, 7, 11, 15-16, 19, 24-26, 35, 37, 39, 40, 43-48, 51, 53, 55, 61, 66, 69, 73, 75-77, 79, 82, 84, 88, 91, 93, 96, 99, 100, 105-109, 113, 116, 117, 119-120,122,124,126-127, 129, 131-136, 138, 140-141,143-144, 146-148, 150, 153-154, 159, 162, 165	1, 5, 8, 13, 14, 17, 18, 20-23, 27, 31-33, 36, 41, 49, 52, 54, 63, 64, 70, 74, 78, 80, 92, 94, 95, 97, 102, 104, 110, 114, 118, 121, 125, 128, 137, 139
S_B=123; g_B- S_B =42; S_B^{ORG}= 76; S_B^{ERP}= 47; $\boldsymbol{R_{m,n,B}^{Form}}$ -; Structural $\boldsymbol{R_{m,n,B}^{Diff}}$ -; $\boldsymbol{R_{1,2,B}^{Dec}}$=1,2; Total cost ($Z_{Beta}$)=39869.382 \$; Total Penalty= 11310.516 \$	

As can be seen in Table 3, out of 123 gaps to be covered, 76 gaps are to be addressed by organizational redesign, improving decentralization from High (1) to Medium (2). This leads to a cost of \$39,869.38 for gap resolution and a penalty of \$13,639.60. Additionally, according to the cost of each gap, it is shown which gaps are being resolved with which strategy. For instance, gap IDs 4, 40, and 71 are resolved by organizational redesign, while gap IDs 1, 21, and 41 are resolved by ERP customization. The same results are obtained for player Gamma, which are not reported here for the sake of brevity. However, for subsidiary Gamma, out of 137 identified gaps, 92 and 45 are determined to be covered by organizational redesign and ERP customization, respectively. Organizational redesign needs to be implemented in decentralization by improving from high to medium.

Moreover, after solving the model, two additional variables are calculated: unused resources = 2,975.49 (man-hours) and unused budget = \$7,674.72. Taking these into consideration, these unused values can be released, which in ERP implementation can help increase the ERP success rate and maintain budget control. If holding Alpha has any preferences for specific gaps to be covered, it can leverage these additional capacities.

The bi-objective optimization model adeptly manages two conflicting metrics of cost and penalty, steering clear of the subjective nature of controversial human judgment. For instance, the Pareto optimal front for the CF module is presented in Figure 1, in which the eventual solution point is obtained by minimizing the distance between the Pareto front and the ideal solution point.

Sensitivity Analysis

In this section, we conduct a sensitivity analysis on the key parameters in our models to assess how variations in these parameters impact the solutions. This includes the number of gaps covered by each subsidiary company, Beta and Gamma, as well as the overall total number of gaps.

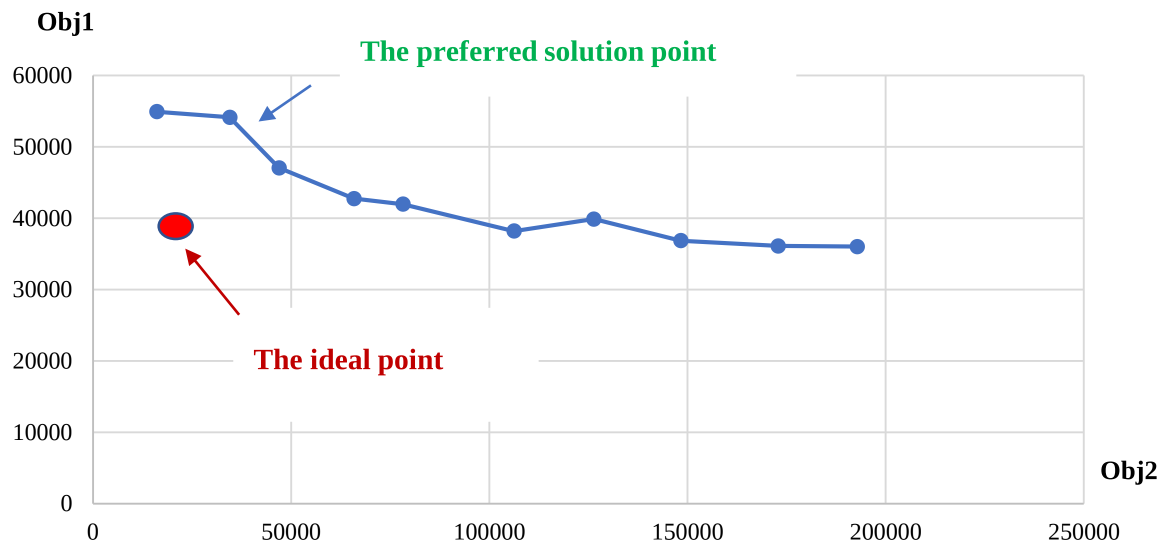

Figure 1. Pareto optimal solutions for CF module

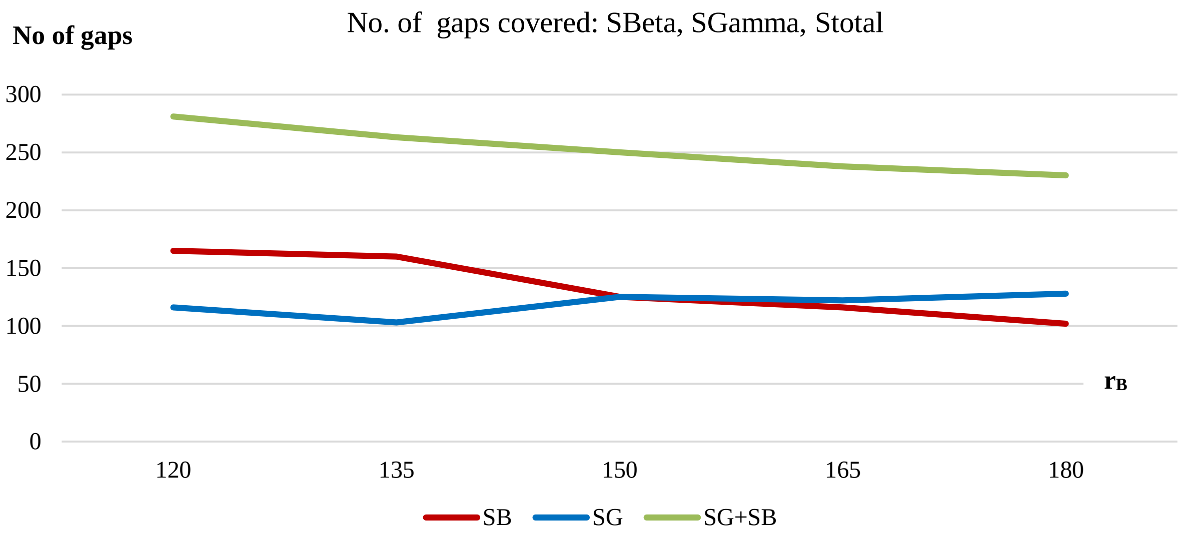

Figure 2. Sensitivity analysis of r_B, representing the average level of resources needed to cover a single gap in the Beta company, and its impact on No. of gaps covered

From the results illustrated in Figure 2, it can be seen that in the game model, an increase in the average resource level needed to cover a single gap in company Beta (r_B) causes the total number of gaps covered by Beta to decrease, and the number of gaps covered by company Gamma to increase, mainly for two reasons: 1) the resources available for covering gaps are constrained as decided by the parent company Alpha, and 2) a Cournot duopoly competition game is engaged between Beta and Gamma.

In addition, an increase in the average cost to cover a gap for company Beta (c_B) or Gamma (c_G) causes fewer gaps to be covered by its competitor, Gamma or Beta respectively, provided that the total budget is constrained, as shown in Figure 3.

Hence, conducting sensitivity analysis, such as the ones described above, are as crucial as developing the quantitative decision procedure in our game and optimization model. It helps company managers at both the parent level (Alfa) and the subsidiaries (Beta and Gamma) make informed decisions regarding the budget and resources required for gap resolution. Additionally, it enables them to prioritize the importance of each gap based on the costs and penalties that each gap could impose on the parent company, Alfa.

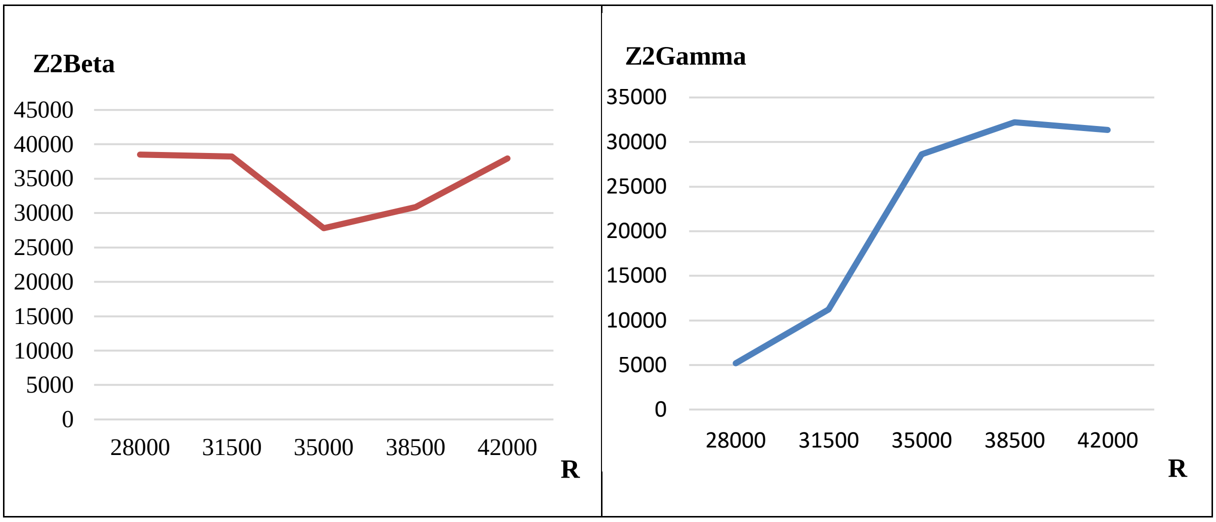

Figure 3. Sensitivity analysis on the total available resource (R) parameter (X-coordinate) versus penalty cost for Beta and Gamma

Conclusions

In this paper, we have reviewed the historical successes and failures associated with ERP implementations highlighting the industry's legacy of employing methodologies predominantly of qualitative and judgment-based approaches, i.e., with limited incorporation of quantitative and algorithmic techniques. To address this research gap, a game and a bi-objective optimization model is developed to systematically improve the ERP implementations success rate by incorporating important factors of relevance including the ideal organizational types, the results of contingency gap analysis, the availability of resources and budget constraints selecting the optimal gap resolution strategies.

The proposed model is designed to identify firstly how many gaps by different entities in an organization can be covered in a Cournet duopoly competition framework, and secondly among them either ERP redesign or Organization redesign would be the chosen optimal strategies considering two objectives of cost and penalty. By integrating concepts and models from management science a novel quantitative decision-making process is developed, which moves away from the existing qualitative-judgment-based approaches. The effectiveness of the proposed model is tested using a real industry case study.

As a potential future study, the game part of the model can further be explored to contain other interactions and diverse conflicting goals existed within a hierarchy of the target organization, e.g., between the holding and the subsidiaries entities realizing that the policies adopted at latter is affected by the former, e.g., using a Stackelberg game model. Additionally, the model can be extended for multi-player dynamics by incorporating multiple stakeholders, as well as considering the time periods in which each contingency gap can be covered requires further analysis and modelling. Another venue for future study is to implement the proposed model as part of decision support systems (DSS) for ERP project managers, providing them with quantitative tools to evaluate and select optimal strategies. These extensions would enhance the proposed model to better reflect the reality of decision-making processes within the organizations and providing valuable insights for ERP involved parties and practitioners based on rigorous quantitative and theoretical foundations.

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