

AN INCENTIVE MECHANISM FOR INTEGRATION OF BUSINESS APPLICATIONS BETWEEN ORGANIZATIONS

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Abstract. Extending services and operations of organizations in the field of e-business or e-government sometimes requires the integration of business applications. However, sometimes due to challenges and risks, such as complex business processes reengineering, upstream organizations are reluctant to integrate their applications. This paper focuses on two critical questions; (1) How can organizations be encouraged to participate in integrating their business applications? (2) What is the amount of incentives required? In this study, cooperative game theory and the externalities of these systems have been considered to form a stable coalition between organizations for integrating their business applications. We provided an algorithm for determining the incentives to integrate the business applications with other organizations in this coalition. These incentives can be extended to various management issues for better decision-making such as economic aspects, public subsidies, and public participation. The results of experiments have shown that creating a coalition based on this strategy is always possible, and the benefits of organizations in the coalition rise with increasing service delivery in business applications.

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1. INTRODUCTION

A *business process* is a collection of related, structured activities or tasks by e-businesses and e-government. A *business application* is employed to support an organization's business processes. The evolution of business applications has been such that at each attempt to support a given business function, a new problem appeared in the connection of that function to other business functions in the e-businesses. This connection is made in business applications by transferring information between applications. This operation is called *integration* if this information transfer occurs through software infrastructure. The goal of integration is to automate information transfer and eliminate manual processes. Integration of business applications has been technically facilitated with service-oriented architectures and technologies such as web services [1, 2], referred to as service in the following.

The constant evolution of information technology means that e-businesses have increasingly complex systems to support their business processes. Beyond a certain point, the coexistence of several business applications used for different purposes, often in isolation, creates enormous difficulties. This issue necessitates integrating these

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applications to support end-to-end business processes. For example, a user must enter information manually from one application to another. This issue causes errors in entering data and delays in receiving information. Suppose any of these business applications do not provide the online services required by e-businesses. In that case, they will face a decline in the efficiency of their operations. In most cases, there is no alternative.

There will always be the need to integrate different applications in a business environment, regardless of how comprehensive each one is. For instance, a new generation of business applications, known as Enterprise Resource Planning (ERP) systems, was created to provide a single, shared system to support a wide range of business functions. However, such an approach did not eliminate the need for more specialized packages to support certain functions. As a result, ERP became one more system to be integrated with other systems in the organization. This issue led to the development of business application integration as an area of its own. This area deals with the problem of connecting all applications, providing message exchange between them, and coordinating the execution of business processes.

The integration of business applications of an e-business plays a vital role in its strategic success [3, 4]. If business applications are in a single organization and intra-organizational integration is required, the top administration can coordinate and support the integration of these applications. But when it is inter-organizational integration, organizations must coordinate with each other. Various forms of inter-organizational integration have been recognized, such as Business to Business (B2B), Business to Government (B2G), Government to Government (G2G), and Government to Business (G2B) [5].

Moreover, inter-organizational integration of business applications is often valuable for profiting or improving the business processes of other e-businesses [6]. In other words, the lack of integration affects other organizations, and the rejection of the challenges and the risks of implementing services does not merely affect the interests of that organization. For example, business applications such as the Household Registration Information System (HRIS), the Land Administration Information System (LAIS), the Commerce Information Systems (CIS), and the Motor Vehicle & Driver Information Systems (MVDIS) could be among the systems of interest in e-Government [7–11].

Inter-organizational coordination is crucial to create data flow between business applications. Organizations face many challenges in establishing this data flow. The great importance of this issue even led to the direct involvement of many governments and the development of policies regarding this issue by preparing Government-wide Enterprise Architecture (GEA) plans. For instance, governments such as Denmark, Australia, and South Korea have developed GEA plans [12]. These plans specify how the business applications should be separated from an engineering point of view in a country and determine the roadmap to move from the current state to the desired state. Although these plans are prepared, governments face problems establishing them. The organizations involved resist implementation due to numerous challenges and risks, such as reengineering complex business processes [13, 14]. The resistance of organizations to implementing business applications and their integration services is evident [15, 16].

Therefore, an incentive for the involved organizations could facilitate implementing GEA plans. In other words, an incentive is required for matters such as encouraging the provision of services by business applications, providing public subsidies such as IT industry subsidies or tax exemptions, and ensuring private sector participation.

The literature consideration on providing an incentive to organizations has been minimal. The focus of the previous studies was on the available services and their properties, such as trust and quality of services. Previous studies have focused on maximizing the benefits of the existing services [17–19] or integrating them [17]. Game theory is a primary tool for predicting economic behavior, including giving incentives. This theory has been the focus of various studies to analyze similar situations in incentive mechanism design [18, 19], and price modeling [20]. To the best of our knowledge, this is the first study that focuses on two critical questions; (1) How can organizations be encouraged to participate (or compensate for the participation costs) in integrating business applications? (2) What is the amount of incentives needed? The answers can be used in management strategies to increase this capacity. These strategies include various management decision-making aspects such as the economic aspects (*i.e.*, how to encourage or reward the provision of information services to other organizations),

public subsidies aspects (*e.g.*, IT industry subsidies or tax exemptions), and public participation (*e.g.*, ensuring private sector participation).

Our goal is to facilitate the formation of a coalition between organizational business applications through actions that encourage the integration of business applications between organizations. To achieve this goal, we have used the cooperative game theory as a mathematical tool to negotiate between two or more players who have different interests [21].

We provide a sustainable way to distribute the benefits of inter-organizational integration of business applications. What we mean by sustainability is that a new coalition or group agreement between organizations cannot improve the sum of the benefits of our approach and cause them to deviate from this strategy. We have analyzed this issue from two perspectives. In the first step, we prioritize the interests of service providers. In the second step, the interests of the organizations using these services are considered. Ultimately, the final answer will be the outcome of these two perspectives. Our experiments examine the proposed solution from various aspects, such as the number of organizations, the number of service side effects, and the ratio of benefits and costs. The results show that the formation of a coalition is always possible. The results also indicate that applying the proposed solution increases the benefits of coalition members and service delivery in business applications. In a nutshell, the most important contributions of this study are as follows:

- (1) To the best of our knowledge, this is the first study to analyze and determine the required incentives for encouraging participation in the integration of business applications between organizations.
- (2) The formation of a stable coalition between organizations has been investigated for integrating their business applications using cooperative game theory and the externalities of these systems.
- (3) An algorithm is presented to distribute the benefits of integrating business applications between organizations and reach the best agreement between the involved organizations.
- (4) The stable existence of a coalition between organizations has been demonstrated through experiments.

The structure of the rest of the paper is as follows: Section 2 provides the literature review. A brief overview of the related definition is provided in Section 3. Section 4 presents the incentive mechanism design and Section 5 provides our cooperative game solution. The experimental results are discussed in Section 6, and finally, the conclusion is presented in the last section.

2. RELATED WORK

The literature can be reviewed from several perspectives. In the following, each of these views has been examined separately. In the end, the importance of this study will be discussed.

2.1. Integration of business services

Some studies considered various aspects of the coalition of business services such as trust, quality of service, cooperation distribution, and managing resources [22–25]. Coronado and Altmann [26] have encouraged the formation of a coalition between organizations to increase the competitiveness of cloud service providers and maximize each organization's benefits. Cohen and Echabbi [27] have analyzed the competitiveness of value-added services provided by cloud service providers and provided a model for revenue sharing. Octavian and Sergiu [28] focused on physical data integration methods for data collection automation to gain a valuable competitive advantage over other businesses. Sani *et al.* [29] provided an integration model with a discussion of the supporting variables and indicators. de Jong *et al.* [30] outline an agenda and delineate B2B service delivery issues that need to be addressed to close the gap between service marketing theory and practice. They also collaborate on developing strategic service capabilities for the industrial marketing space. Gomathy and Rajalakshmi [31] discussed agile integration of different business silos using Service Oriented Architecture. This solution and its core technology enable the business enterprise systems to be flexible and loosely coupled.

In most of these studies, the focus has been on maximizing the benefits of providing business application services. Our goal has been different. Specifically, we have focused on providing incentives for an organization to

participate in delivering services cooperatively, and we have analyzed its specific strategy. This analysis ensures the efficiency of the allocated payoff.

2.2. E-business and E-government

Facilitating service delivery and integration in e-business and e-government was considered by other studies. Vilnai-Yavetz and Levina [32] examine the users' motives for sharing content and communication strategies in social networking services. Al Nidawy *et al.* [33] considered trust as one of the determiners in e-government services and provided an understanding of the constructs of trust in this regard. Sokiyna and Aqel [15] investigated the roles of electronic business application software from three dimensions and explored if these dimensions affect collaboration between departments and operational excellence. The results confirmed the mediating impact of department collaboration using sustainable software on operational excellence. Rima Kabrilyants *et al.* [34] demonstrated a significant effect of e-business implementation success and IT capabilities on organizational capabilities.

Yang *et al.* [10] explored the boundaries of cross-boundary information sharing and integration in a case study. Oyekunle and Tiarniyu [35] considered deploying information technologies to drive business processes. They promise substantial gains for institutions using technology, organization, and environment framework.

Although the studies have identified barriers or motives to the integration of business applications and how to overcome them, the emphasis has been placed on removing specific barriers. We believe that the challenges of this issue itself constitute a significant obstacle, and our focus has been on providing incentives. We have used the incentives to organizations as a motivating factor in accelerating the removal of these barriers.

2.3. Supply chain management

Some researchers have addressed similar issues in supply chain management. In this regard, Ferrell *et al.* [36] reviewed the possible opportunities for horizontal collaboration between logistics service providers and discussed the efforts made. Falagara Sigala and Wakolbinger [37] considered outsourcing humanitarian logistics to upstream business companies. They have provided incentives for this issue and raised the role of business goals, risks, and stakeholder goals. Selviaridis [38] has studied service co-production and limited provider capability and examined the impact of performance attribution and its antecedents as an influential factor in service delivery.

The nature of business application services is different from logistics services. In most cases, providing business application services is not part of the business and core activities of the organization. The focus of these studies has been on key activities of the organization. The innovation of this article is in developing a solution independent of the organization's core activities. The emphasis is on the positive side effects of inter-organizational integration of the business applications and supplying sustainable incentives to the information service provider.

2.4. Coalition formation

A coalition as a group of parties aims to work jointly to earn much more gains due to their cooperation. This paper examines the agreement between organizations by forming a coalition. The issue of coalition formation between groups of individuals has been considered in various studies to achieve a common goal. In this regard, Mahdiraji *et al.* [39] present a review of coalition formation games from theoretical foundations and coalition structure. Sklab *et al.* [40] addressed the issue of acquiring the group goals of the coalition gradually with dynamically changing externalities. Hadjres *et al.* [41] considered a coalition formation for clients' SLA requirements during the coalition formation process or providing a self-healing mechanism to deal with unexpected resources shortage during operation. Arif [42] presents an evolutionary algorithm (EA)-based task allocation framework for improved, deadlock-free solutions against time-extended multi-robot coalition formation.

However, in these studies, forming a coalition has been considered for different motives. The coalition formation has been considered gradual concessions or between existing services, and the initial incentives to engage the members in the coalition have not been considered.

2.5. Discussion

Previous studies show that attention to allocating initial incentives to the organization involved in integrating business applications has been minimal. Past studies in the integration field have focused more on optimizing the use of existing services and their integration. Existing studies in the field of e-business have focused more on identifying obstacles in the integration of services or trying to solve them. Even the investigations carried out in other areas, such as supply chain management, show that the techniques introduced cannot be suitable for integrating these services. In this study, as far as we know, the issue of initial incentive allocation to organizations has been addressed for the first time. These incentives can be allocated through subsidies, tax exemptions, and encouraging private sector participation. These incentives help organizations show less resistance to the existing challenges in integrating business applications and facilitate this path. We have also determined the amount of incentive required.

Using coalition formation games, we used game theory to analyze the required incentive to analyze this economic situation [39]. Game theory has always been of interest in analyzing equilibrium and the determination of a stable point. Similar cases, such as social structure formation [43,44], resource allocation, aggregation [45,46], and optimization [47], used this technique to analyze the problem. The coalition formation allows organizations to cooperate and create benefits that arise from the integration of business applications. This article has used cooperative game theory to analyze the interaction and cooperation between organizations. Furthermore, an algorithm is presented to distribute the benefits between these organizations in this coalition sustainably.

3. BACKGROUND

This section will provide a brief overview of the concepts and definitions of cooperative game theory used in this article:

- **Cooperative game:** a game involving a pair (P, v) in which P is a limited set of players that we know as organizations and companies. $v : 2^P \rightarrow \mathbb{R}$ is also a characteristic function for the game, and $v(F)$ indicates the worth of the $F \subseteq P$ coalition. The worth of F is the value of benefits that players in F can create for themselves without the cooperation of others. $v(\emptyset) = 0$.
- **Additive cooperative game:** a cooperative game in which $v(F) = \sum_{i \in F} v(\{i\})$ for $F \subseteq P$. This means that there is no benefit in cooperation, and the coalition does not help to increase the benefits of the players.
- **Imputation:** one of the goals of a cooperative game is to determine an acceptable agreement on how to distribute the benefits among the players. There are two possible ways to do this. The first method, called stability, seeks to find a distribution in which the players of a game cannot increase their profits by leaving the coalition, and in fact, the distribution is the best distribution for them. The second method is based on equality and tries to make an allocation based on justice. The imputation in a cooperative game is an allocation of $x \in \mathbb{R}^N$ so that satisfy $\sum_{i \in P} x_i = v(P)$ and $x_i \geq v(\{i\})$ for all $i \in P$. The first condition stipulates that the entire value of the coalition must be fully distributed among the members. The second condition stipulates that no player should earn less than what he or she earns on his or her own. We show this imputation with $I(P, v)$.
- **Core:** the core of a cooperative game is a set of imputations defined as follows:

$$\text{Core}(P, v) = \left\{ x \in I(P, v) : \sum_{i \in P} x_i \geq v(F) \text{ for all } F \subset P \right\}. \quad (1)$$

In other words, the core is the set of imputations of game payoffs between players that are stable based on previous explanations, and the deformation of the coalition itself cannot improve performance. Figure 1 shows a view of the core set between 3 players. Nevertheless, the core may be empty, and there may be no imputations of payoffs under these conditions.

On the other hand, the number of elements in the core set may be substantial. In this situation, selecting from this set requires appropriate criteria. But at the same time, if the cooperative game is an additive game

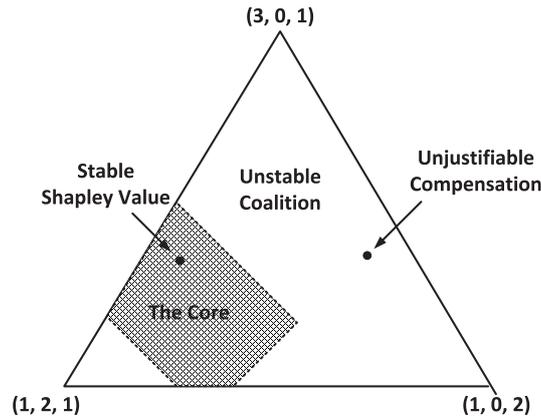


FIGURE 1. The core of 3 players.

due to the uniqueness of the core $\text{Core}(P, v) = \{x\}$ when $x_i = v(\{x\})$ for all $i \in P$ both problems will be solved. In the following, we will identify the appropriate core by converting the game to an additive game.

- **Sharing strategy:** in a cooperative game, players donate part of their payoffs to the players who do not benefit enough from participating in the game. In this game, a vector in the form of $\varphi(P, v) \in \mathbb{R}^N$ determines how the distribution of benefits between players should be. It is clear that $\sum_{i \in P} \varphi_i(P, v) = v(P)$. A sustainable sharing strategy must be in the core.
- **Shapley value:** one of the best sharing in a cooperative game is Shapley value [48]. In a limited set of P , consider Γ_P as the set of all P sequences. Considering $\pi \in \Gamma_P$, $\text{Pre}(i, \pi)$ can be considered to represent the set of P elements that appear before i in the sequence specified in π . In other words, $\text{Pre}(i, \pi) = j \in P \parallel \pi(j) < \pi(i)$. Based on this, the Shapley value of a cooperative game for all $i \in P$ is defined as follows.

$$Sh_i(P, v) = \frac{1}{n!} \sum_{\pi \in \Gamma_P} [v(\text{Pre}(i, \pi) \cup \{i\}) - v(\text{Pre}(i, \pi))]. \tag{2}$$

However, the Shapley value may be outside the core, and therefore is not a sustainable sharing strategy (unjustifiable compensation in Fig. 1). So we have been looking for an alternative solution that can share sustainably.

- **Convex cooperative game:** for each cooperative game, the game is convex, in other words

$$v(S \cup T) + v(S \cap T) \geq v(S) + v(T) \quad \forall S, T \in P. \tag{3}$$

4. INCENTIVE MECHANISM DESIGN

In this section, we first define the problem of the inter-organizational coalition of business applications services and provide some examples. Subsequently, cooperative game theory is considered to analyze this situation. When the core of the game is not empty, and the Shapley value is inside the core, this value can be easily used to distribute the benefits between organizations. In other words, organizations can make more money if they compensate for some of the costs of service providers. In this case, the organizations adhere to the fact that they will achieve more payoffs than the non-cooperative state, and unintended withdrawal from the coalition will reduce their payoffs. The payoff equals benefits minus costs.

However, we will show that when a provided service has low externalities, the Shapley value can be out of the core, and organizations may not adhere to it. Also, the core may be empty, and it is impossible to find a distribution of payoffs. Therefore, we will provide a solution and algorithm to solve this problem, which is

TABLE 1. The parameters used in the model.

Parameter	Description
s	The payoff of providing specific services are displayed by $s \in \mathbb{R}_+^N$ vector. In other words, when an organization $i \in F$ provides a specific service, the payoff is $s_i \in \mathbb{R}$
g	The payoff of providing general services by organizations are displayed with the $g \in \mathbb{R}_+^N$ vector. The organization payoff is $g_i \in \mathbb{R}$ if it does not provide specific services
E	The externality of the services is displayed by the matrix $E = (e_{ij})_{i,j \in P}$ where the organization i provide a service to the organization j . So that when $(i, j) \in G$ then $e_{ij} > 0$ (service path) otherwise $e_{ij} = 0$. These externalities are specified according to the need of the organization to the service

based on turning the externalities of services into payoffs for service providers. In this way, the game becomes an additive game. By definition, since there is a single core for an additive game, the answer will be clear.

4.1. The Problem

We consider some organizations intend to form a coalition to improve the payoff of services. We assume that these organizations are only affected by the services. On the other hand, in two-way communication between organizations in which two or more organizations provide mutual services to each other, there is sufficient motivation for a coalition. Since the goal of our research is to focus on a situation where there is not enough motivation, two-way communication is not of interest to us. Therefore, by considering the organizations providing services and the organizations that use those services, we can consider a directional graph G . The nodes of this graph are players P (organizations) and $(i, j) \in G$ means that the organization i is a service provider to j . *i.e.*, the service provided by organization i is used by organization j .

Given the purpose of this study and to simplify the model, we consider two models of inter-organizational services [49]. The first form is the services that are expressly provided by organizations for the use of specific organizations. Providing these services requires negotiation and development of the organization’s business applications, *i.e.*, providing custom APIs and web services, custom business processes, etc. We recognize this type of service as a specific-purpose service (in short as a “specific service”). The second form is the services that are available or being presented to the general through existing portals of the organization, *i.e.*, the organization’s websites and user interfaces, databases, and other communication channels. We name it a “general service”. The use of special services leads to better information flow between organizations and has higher benefits for them. However, if organizations do not provide specific services, other organizations can use general services with limited benefits. The symbols and parameters used below are presented in Table 1.

We have already mentioned that the provision of services by upstream organizations will bring more payoff to other organizations. If these services are not provided, then the organizations affected by these services can provide less valuable or delayed services and operations. The provision of many services by downstream organizations depends on the provision of essential services in upstream organizations. This is considered by the following assumption in the model.

Assumption 1. $(i, j), (j, k) \in G$ would mean that $(i, k) \in G$ and $e_{ik} \geq e_{jk}$.

Now we can define the problem of forming a coalition between the business applications services of organizations as (P, G, s, g, E) and a cooperative game (P, v) . Accordingly, the worth of coalition F is determined by the following maximization problem:

$$v(F) = \max_{S \subseteq F} \Delta(S, F, s, g, E) \tag{4}$$

$$\Delta(S, F, s, g, E) = \left\{ \sum_{i \in S} s_i + \sum_{j \in F \setminus S} g_j + \sum_{i \in S, j \in F \setminus S} e_{ij} \right\} \tag{5}$$

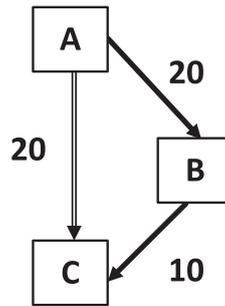


FIGURE 2. The externality graph of the perfect example.

where $\sum_{i \in S} s_i$ is the payoff of providing specific services by organizations, $\sum_{j \in F \setminus S} g_j$ is the payoff of providing general services and $\sum_{i \in S, j \in F \setminus S} e_{ij}$ is the externality of these services. We call each answer for $\max_{S \subseteq F} \Delta(S, F, s, g, E)$ an optimal arrangement for F . In other words, an optimal arrangement is any combination of organizations providing specific or general services and their externality that can create the maximum value for F . In the following, the worst possible cases are illustrated by different examples.

4.1.1. Perfect example

In this example, the coalition between the three organizations is examined. The set of organizations, the payoffs of providing specific and public services are $P = \{A, B, C\}$, $s = (10, 9.9, 20)$ and $g = (20, 10, 10)$, respectively. The externality graph of providing services is $G = \{(A, B), (B, C), (A, C)\}$, which is shown in Figure 2. Accordingly, organization A is merely a service provider, organization C is simply a service applicant, and organization B is both a service applicant and a service provider. We assume that if organization A provides a specific service, the payoffs of organizations B and C will increase by 20 units. However, if organization B provides specific services, the payoff of organization C increase by 10 unit. In other words, $e_{AB} = e_{AC} = 20$, $e_{BC} = 10$, and in other cases $e_{ij} = 0$.

We will first look at this example in a non-cooperative way. In other words, organizations receive only the payoffs of their activities and do not compensate for each other. We compare this model with the cooperative method. In the non-cooperative method, the choice of strategy is based on the assumption of the relative rationality of the organizations and iterated elimination of strictly dominated strategies [50].

The possible payoffs of organizations in this example are developed in the form of a tree in Figure 3. Here, each organization can have two strategies for providing specific services (s) and general services (g). The user payoff is displayed based on user selections on tree leaves. The first, second, and last payoff is related to A , B , and C , respectively. Accordingly, if organization A chooses to provide general services, it will get more payoff (20 units) than providing specific services. This payoff is independent of the choices of other organizations.

Similarly, if organization B chooses to provide general services, this will result in a higher payoff (10 units) than providing specific services (9.9 units). This choice is independent of the decision of organization C . It is clear that due to the higher payoff of the specific service (20 units), organization C selects this type of service. So, the choices of the organizations here are to provide general service, general service, and specific service by organizations A , B , and C , respectively. While the provision of specific services by organization A is more valuable to organizations and cannot be achieved in this way. On the other hand, the maximum possible payoff for organizations will be (20, 10, 20), respectively.

In the following, we show that by cooperatively solving the problem, the desired result can be achieved, and more payoff can be created for the organizations. In this regard, the organizations compensate for some of the payoffs of other organizations to achieve more benefits. We first show the optimal arrangement of all three subsets of these three organizations in Table 1. We show that whether deviating from the coalition of all organizations (row 7) and forming an internal coalition can achieve more payoffs or not.

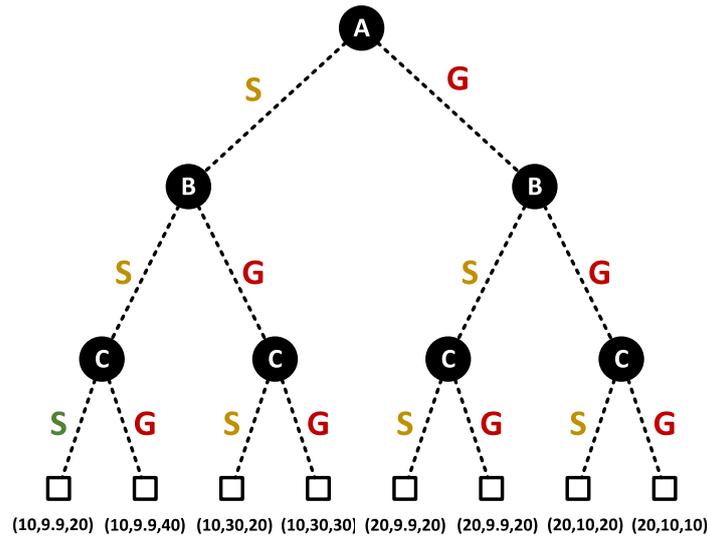


FIGURE 3. The extensive form representation of the perfect example.

For example, organizations *A* and *B* form a coalition between their services in row 4. The best value of this coalition is obtained when organization *A* is a specific service provider, and organization *B* is a general service provider. In this case, the benefits of providing specific services to organization *A* are equal to 10. The benefits of providing general services to organization *B* are equal to 10, and the externality of organization *A* service for organization *B* is equal to 20, which is 40 units of value for this coalition. It is the maximum value that this coalition can create.

In the 7th-row (the situation in which organization *A* provides specific services, and two other organizations use it), the direct payoffs of organizations are 10, 30, 30, respectively. The payoff of organization *A* has decreased from 20 to 10 compared to the non-cooperative method. Therefore, organization *A* logically does not want to provide this service. We agree in a cooperative way that organizations pay part of their payoffs to organization *A* and compensate for its costs. As mentioned, one of the ways to distribute payoffs among organizations is the Shapley value. This value in this case is equal to $Sh(P, v) = (28.3, 18.3, 23.3)$. It means that organizations *B* and *C* should transfer 11.7 and 6.7 units of their payoffs to organization *A*, respectively. This distribution not only increases the payoff of organization *A* but also encourages it to provide specific services. It also provides higher payoffs than non-cooperative methods for organizations *A* and *B* (8.3 and 3.3 units, respectively).

In this example, the core of the game is not empty; The mentioned distribution was possible, and the amount of Shapley value was inside the core. It means that organizations achieve higher payoffs in this way, and they cannot achieve more significant payoffs by leaving this coalition and forming a smaller internal coalition. Unfortunately, this is not always the case. In other words, sometimes, the core of the game is empty, or Shapley's value is not inside the core. These situations arise when the costs of providing services to other organizations are not justified. This situation happens in two cases. (Eq. (2)) Compensation is unjustifiable, or the externality of services is low. (Eq. (3)) There is no proportionality between the benefits of the service and what is stated in Assumption 1. These situations are described in the following examples.

4.1.2. Unjustifiable compensation example

In this example, we show what happens when five organizations form a coalition where the services of some organizations have a little externality on other organizations. In this set of organizations, the payoffs of providing special and general services are $P = \{A, B, C, D, E\}$, $s = (0, 0, 0, 0, 10)$ and $g =$

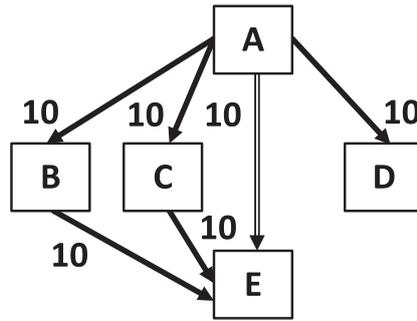


FIGURE 4. The externality graph of unjustifiable compensation example.

$(10, 0, 0, 0, 0)$. The externality graph of the services provided by the organization is in the form of $G = \{(A, B), (A, C), (A, D), (A, E), (B, E), (C, E)\}$ (Fig. 4). $e_{ij} = 10$ for all $(i, j) \in G$.

The maximum value obtained from the optimal arrangement of all organizations in this example is $v(P) = 40$. For example, if we consider organizations A and E as providers of specific services, the use of these services only benefits organizations B, C, D , and because $e_{Ai} = 10$ for each of the $i \in B, C, D$, then this use creates 30 units of benefit for them. Also, organization E generates a total of 40 units of payoff due to providing the specific service, and $s_E = 10$. The Shapley value, in this case, is $Sh(P, v) = (15, 5, 5, 4.2, 10.8)$. It means that each of the organizations B, C , and D must pay 5, 5, and 5.8 units to compensate for the services of two specific service providers.

However, in this case, if we do not consider the organization E in the coalition, then $v(\{A, B, C, D\}) = 30 > \sum_{i=1}^4 Sh_i(P, v) = 29.2$ which means that if organizations get out of the above coalition and form an internal coalition themselves, they will be more efficient.

In this sense, $Sh(P, v) \notin Core(P, v)$. Of course, this makes sense because other organizations pay a fee for the E organization for which there is no justification, and its services have not been used. Therefore, any distribution of payoffs that is not from the core does not create commitment for the organization, and this will mean potential losses for the organization.

However, in this example, $Core(P, v)$ is not an empty set. For example $(10, 0, 10, 10, 10) \in Core(P, v)$. This payoff can be obtained by considering $S = \{A, E\}$ and requiring organization B to pay 10 units to organization A in return for receiving specific services. In this case, no coalition of organizations outside of this coalition can increase their efficiency, and this means that they adhere to this coalition. It demonstrates the need to distribute payoffs within the core and shows that the Shapley value cannot be the right choice. In the following example, we show that the core of the game can be empty when the externality of upstream services is not higher, and in other words, Assumption 1 is not established.

4.1.3. Empty core example

In this example, the coalition between the five organizations is examined. In this set of organizations, the payoffs of providing special and general services are $P = \{A, B, C, D, E\}$, $s = (0, 0, 0, 0, 0, 10)$ and $g = (10, 0, 0, 0, 0)$.

In this case, the graph $G = \{(A, B), (A, C), (B, E), (C, D), (D, E)\}$ (Fig. 5) determines the externality of the service. $e_{AB} = e_{AC} = e_{BE} = e_{CD} = e_{DE} = 10$ and $e_{ij} = 0$ for other cases. The value of the optimal arrangement of coalitions consisting of 4 or 5 organizations is presented in Table 2.

In this example, where $F = P$, the provision of specific services by organization E will not have an applicant. On the other hand, if there is a core, then each of its selected elements must create a worth greater than 20 to bind organizations. Because the independent coalition of organizations A, B, C , and D in row 1 creates 20 units of worth.

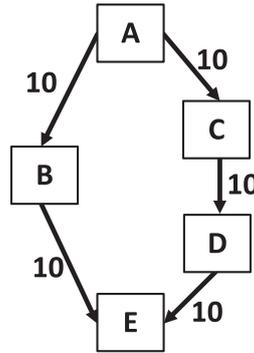


FIGURE 5. The externality graph of empty core example.

TABLE 2. The worth of some of the optimal arrangements in empty core example.

	Organizations (F)	Specific providers	General providers	Worth of $F(v(F))$
1	A, B, C, D	C	A, B, D	20
2	A, B, C, E	A, E	B, C	30
3	A, B, D, E	B, D	A, E	30
4	A, C, D, E	C, E	A, D	30
5	B, C, D, E	C, E	B, D	20
6	A, B, C, D, E	A, E	B, C	30

Similarly, the selected element of the core must be able to create a worth greater than 20 for the coalition of organizations B to E according to row 5. For rows 2–4, this value must be greater than 30. The coalition of all five organizations needs to be more than 32.5. Nevertheless, this is not possible because the maximum possible value for the coalition of all organizations $v(P)$ is 30, according to row 6. So by definition, the core is empty. We will examine the reasons for this situation and then provide a solution to this situation.

Based on Assumption 1, we pointed out that providing services by upstream organizations will be of greater benefit to organizations; the provision of these services should create higher benefits in the externality graph. If these conditions are not met, it will lead to a lack of balance in the distribution of benefits in the coalition of organizations, and the result will be the emptiness of the core.

5. THE SOLUTION

As mentioned, there are two problems with stable distribution. First, the core may be empty. Second, the Shapley value may be out of the core. Our solution is to provide an algorithm to turn externality into a payoff for service providers until the game is turned into an additive game. Because the additive game has a single core, the answer is obvious. In the following, we first show that this solution provides the answer to the problem.

Proposition 1. *If there is a game (P, z) where the condition $v(F) \leq z(F)$ is established for all $F \subset P$ and $v(P) = z(P)$, according to Formula 1, this means $\text{Core}(P, z) \subseteq \text{Core}(P, v)$.*

Therefore, the non-emptiness of $\text{Core}(P, z)$ will indicate the non-emptiness of $\text{Core}(P, v)$, and *vice versa*. Each distribution of payoffs from the core set (P, z) is also a distribution of payoffs from the core set (P, v) . On the other hand, if the externality graph is empty, then the game is additive. According to the definition, there is a unique answer to the additive game, and its core is not empty.

TABLE 3. Transform perfect example to a balanced coalition.

	Reduce external- ity on the graph	Increasing the payoff of organi- zations	Proposition 1 conditions
1	Reduce e_{AB} from 20 to 9.9	Increase s_A from 10 to 20.1	$v(\{A\})$ and $v(\{A, C\})$ are increased, while $v(F)$ and $v(P)$ remain unchanged. This change also causes $S = \{A, B\}$ To be introduced as a new optimal arrangement
2	Reduce e_{BC} from 10 to 0 (remove edge (B, C))	Increase s_B from 9.9 to 19.9	$v(\{B\})$ and $v(\{B, C\})$ are increased. In addi- tion, the adjacency of nodes A and C is lost
3	Reduce e_{AC} from 20 to 10	Increase s_A from 20.1 to 30.1	$v(\{A\})$ and $v(\{A, B\})$ is increased. This change also introduces two new configurations $S = \{A, C\}$ and $S = \{A, B, C\}$
4	Reduce e_{AB} from 9.9 to 0 (remove edge (A, B))	Increase g_B from 10 to 19.9	$v(F)$ does not change
5	Reduce e_{AB} from 10 to 0 (remove edge (A, B))	Increase g_C from 10 to 20	The graph is balanced

To achieve an additive game, we start our algorithm by reducing the externalities on the graph and increasing the payoff of providing specific and general services. However, we mentioned in the examples that if Assumption 1 is not established, a balance in the distribution of payoffs may not always be possible. We distribute the payoffs in this way until the game is balanced. Then we complete the algorithm to turn the problem into an additive game. By our definition, if the adjacent organizations in the externality graph are either both specific service providers or not, then the game is balanced. For example, the perfect example is not balanced, as the only optimal arrangement is $F = \{A\}$, and no two adjacent organizations are providing specific services or *vice versa*. However, the empty core example is balanced because these conditions are in place.

The steps for balancing the game and transmitting externalities to the payoffs of organizations are presented using an intuitive sample in Table 3, and in the following sections, the algorithm is presented.

By completing the steps in Table 3, the problem is now balanced. Fortunately, in this example, the externality graph is empty, and it is additive. Now if we consider the balanced problem (P, z) then $\text{Core}(P, z) = \{(30.1, 19.9, 20)\}$ and since the conditions of Proposition 1 are established, we can conclude that $(30.1, 19.9, 20) \in \text{Core}(P, v)$. However, as we mentioned, this algorithm does not always empty the externality graph.

For example, consider a change in the perfect example. The payoff of providing specific and general services are $P = \{A, B, C\}$, $s = (0, 0, 10)$ and $g = (10, 0, 0)$, respectively. Besides, the externality graph of $G = \{(A, B), (B, C), (A, C)\}$ is similar to the perfect example, but the externalities are $e_{AB} = e_{AC} = e_{BC} = 10$. In other words, Assumption 1 is violated. The value of the coalition and the optimal arrangements are shown in Table 4. In this table, it is clear that the coalition is balanced. Because if we consider each pair of organizations, then there is an optimal arrangement that either includes both of them or does not include either of them. For example, for organizations A and B , both $\{A, B\}$, and $\{C\}$ are optimal arrangements.

Here, we cannot remove the edges of this graph by increasing or decreasing g or s , as this increases $v(P)$, and this empties the core. However, our inspection has shown that as an alternative in these cases, you can remove edges from the graph without making any changes to the game. Removing the edge (A, B) or (B, C) causes Assumption 1 to be established and the game to be additive. This removes the core from being empty.

Proposition 2. *In a balance coalition either $G = \emptyset$ or there is an edge (i, j) so that by removing it $v(F) = v^{-ij}(F)$ for all $F \subseteq P$ without any other changes in the graph and the game.*

TABLE 4. Optimal arrangements in assumption violation example.

	Selected organizations (F)	Optimal arrangements	Worth of $F(v(F))$
1	A	\emptyset	10
2	B	$\emptyset, \{B\}$	0
3	C	$\{C\}$	10
4	A, B	$\emptyset, \{A\}, \{B\}$	10
5	A, C	$\{C\}$	20
6	B, C	$\{B\}, \{C\}, \{B, C\}$	10
7	A, B, C	$\{A\}, \{B\}, \{C\}, \{A, B\}, \{A, C\}, \{B, C\}$	20

TABLE 5. The result of sharing strategies.

	$v(P)$	Distribution for service providers	Distribution for service applicants	Average distribution
Perfect example	70	(30.1, 19.9, 20)	(20, 20, 30)	(2.505, 1.995, 2.5)
Unjustifiable compensation example	40	(10, 10, 10, 0, 10)	(10, 10, 10, 0, 10)	(10, 10, 10, 0, 10)
Empty core example	20	(10, 0, 10)	(10, 0, 10)	(10, 0, 10)

We have evaluated the proof of this statement by randomly and extensively examining the search space in the experimental evaluation section. Nevertheless, the next question is whether this algorithm can always find a game that covers the conditions of Proposition 1.

Theorem 1. *In any game (P, v) that considers Assumption 1, there is a balanced game (P, z) with a maximum of the same number of edges, which in addition to covering Assumption 1 also includes the condition $v(S) \leq z(S)$ for all $S \subset P$ and $v(P) = z(P)$.*

Proof. If we consider the set of all adjacent organizations in the $G(i, j)$ graph, both of which are specific service providers at the same time or not, and there is no optimal arrangement for them then we take into account the following conditions:

$$\Phi = \left\{ (i, j) \in G : \max_{S \subseteq P: \|S \cap \{i, j\}\| \neq 1} \Delta(S, F, s, g, E) < v(P) \right\}. \tag{6}$$

The induction on the cardinality of Φ and G is used to prove this. In the first step, we know that if $G = \emptyset$, then there is no externality, and (P, v) is balanced, so $z = v$. In the second step, we assume that the result is established when the graph's cardinality is $|G| - 1$ or less. Now, It is clear that if $\Phi = \emptyset$ then (P, v) is balanced and $z = v$.

Now suppose $\Phi \neq \emptyset$. Without losing the generality, it can be assumed that A and B are members of the set Φ such that A is before B in graph G . Assume that there is no optimal arrangement for both A and B as specific service providers (a similar case happens when none of them is a specific service provider). If $S' \in \max_{S \subseteq P: A, B \subseteq S} \Delta(S, F, s, g, E)$ is considered as an arrangement with a maximum value that both A and B are specific service providers, then considering the previous definitions, we know that this arrangement is not optimal. It means that there is an optimal arrangement such that $S'' \subset P$ where $\alpha = \Delta(S'', F, s, g, E) - \Delta(S', F, s, g, E) > 0$.

Now suppose $\Phi = \emptyset$. Without losing the generality, it can be assumed that A and B are members of the set Φ such that A is before B in graph G . Assume that there is no optimal arrangement for both A and

B as specific service providers (a similar case happens when none of them is a specific service provider). If $S' \in \max_{S \subseteq P: A, B \subseteq S} \Delta(S, F, s, g, E)$ is considered as an arrangement with a maximum value that both A and B are specific service providers, then considering the previous definitions, we know that this arrangement is not optimal. It means that there is an optimal arrangement such that $S'' \subset P$ where $\alpha = \Delta(S'', F, s, g, E) - \Delta(S', F, s, g, E) > 0$.

Because A and B are both adjacent and A is present before B in the graph, $e_{AB} > 0$. Therefore, if we consider $\alpha' = \min(\alpha, e_{AB}) > 0$ (similar to Tab. 3), we can play a new cooperative game (P, v') by considering $s'_A = s_A + \alpha'$ and $e'_{AB} = e_{AB} - \alpha'$, and also $s'_i = s_i, g'_i = g_i, e'_{ij} = e_{ij}$ in other cases.

Because (P, v) covers Assumption 1, then (P, v') also covers this assumption. Therefore, S'' is an optimal arrangement for (P, v') and $v'(P) = v(P)$. Moreover, for each $F \subseteq P$, the condition $v(F) \leq v'(F)$ is satisfied; Inequality occurs when $A, B \in F$, and there is an optimal arrangement in F so that both A and B provide specific services. There are two cases in this situation.

In the first case, if $\alpha' = e_{ij}$ and A and B are not adjacent to (P, v') , then induction on $|G|$ can be used. In the second case, if $\alpha' = \alpha$ and F in (P, v') form an optimal arrangement, then induction on $|\Phi|$ can be used. Induction induces that there is a balanced coalition game (P, z) that satisfies Assumption 1. Moreover, if the conditions for (P, v) are met, then the condition $v'(F) \leq z(F)$ will be established for all $F \subset P$ and $v'(P) \leq z(P)$. Since $v'(F) \leq v(F)$ is established for all $F \subset P$ and $v'(P) \leq v(P)$, the proof is done. \square

5.1. Sharing strategy

We showed that a sustainable distribution of benefits between organizations could be found. To this end, Algorithm 1 shows how to reduce the externality e_{ij} and increase the payoff of providing specific services (s_i). Similarly, Algorithm 2 does the same thing to increase the payoff of providing general services.

Algorithm 1. Transfer externality to specific services payoff.

Input: P, G, s, g, E

Output: Modified s and G

```

1: procedure TRANSFEREXTERNALITYTOTHE SPECIFICPAYOFF
2:    $\alpha = v(P) - \max_{\{i,j\} \subseteq S} \Delta(S, F, s, g, E)$ 
3:   if  $\alpha > 0$  then
4:     if  $\alpha \geq e_{ij}$  then
5:        $s_i = s_i + e_{ij}$ 
6:       Discard the edge between  $i$  and  $j$ 
7:     else
8:        $s_i = s_i + \alpha$ 
9:        $e_{ij} = e_{ij} - \alpha$ 

```

We have presented three strategies based on prioritizing these distributions. First, the payoff of service providers is improved; the transfer of payoffs to service providers is done first. Second, the payoff of service applicants is improved, and finally, the average of these two solutions is considered.

5.1.1. Favorable sharing for service providers and service applicants

According to Theorem 1, Algorithm 3 shows the required steps to balance the game. This algorithm performs the distribution in such a way that the payoffs of the service providers are further served. This is done by prioritizing the increase in the payoff of specific services (s_i). This algorithm examines the externality graph in the second line. The edges that are at higher levels of the graph are selected first. In other words, edges between organizations that provide services must be selected first. After the transfer of payoffs to service providers has ended at line 3, the transfer of payoffs to general service providers will take place at line 4. Finally, the unused edges at line 6 are removed according to Proposition 1. If there is more than one edge, priority should be given

Algorithm 2. Transfer externality to general services payoff.

Input: P, G, s, g, E

Output: *Modified s and G*

```

procedure TRANSFEREXTERNALITYTOTHEGENERALPAYOFF
2:    $\beta = v(P) - \max_{S \cap \{i,j\} = \emptyset} \Delta(S, F, s, g, E)$ 
   if  $\beta > 0$  then
4:     if  $\beta \geq e_{ij}$  then
        $g_i = g_i + e_{ij}$ 
6:     Discard the edge between  $i$  and  $j$ 
     else
8:        $g_i = g_i + \beta$ 
        $g_{ij} = g_{ij} - \beta$ 

```

to the edge at the lower level of the graph. In this way, more services are provided to service providers. By removing all the edges, we have an additive game, and finally, in the last line, the result vector is returned as the only remaining solution. The algorithm for sharing benefits to service applicants is similar and only priority is given to increasing the payoff to general services. This algorithm is presented in Algorithm 4.

Algorithm 3. Favorable sharing strategy for service providers.

Input: $P, G, s, g, E, method$

Output: *Payoff distribution between organizations (x)*

```

1: procedure FAVORABLESHARINGFORSERVICEPROVIDERS
2:   for each  $i \in G, j \in G$  where  $i$  and  $j$  are adjacent
3:     TransferExternalityToSpecificPayoff()
4:     TransferExternalityToGeneralPayoff()
5:   end for
6:   Discard unused edge by any coalition  $F \subseteq P$ 
7:   if there is an edge in  $G$  then
8:     go to 2
9:   return  $x_i = \max(s_i, g_i)$ 

```

Algorithm 4. Favorable sharing strategy for service applicants.

Input: $P, G, s, g, E, method$

Output: *Payoff distribution between organizations (x)*

```

1: procedure FAVORABLESHARINGFORSERVICEAPPLICANTS
2:   for each  $i \in G, j \in G$  where  $i$  and  $j$  are adjacent
3:     TransferExternalityToGeneralPayoff()
4:     TransferExternalityToSpecificPayoff()
5:   end for
6:   Discard unused edge by any coalition  $F \subseteq P$ 
7:   if there is an edge in  $G$  then
8:     go to 2
9:   return  $x_i = \max(s_i, g_i)$ 

```

TABLE 6. The worth of optimal arrangement in the perfect example.

	Coalition F	Specific service providers	General service providers	Worth of $F(v(F))$
1	A		A	20
2	B		B	10
3	C	C		20
4	A, B	A	B	40
5	A, C	A	C	40
6	B, C	B	C	29.9
7	A, B, C	A	B, C	70

5.1.2. Average sharing

The last solution considers the average of the previous two solutions as y . It should be noted that due to the convexity of the core, this response will be a member of the $y \in \text{Core}(N, v)$.

5.1.3. Sample sharing

The results of the implementation of the three solutions over the examples are presented in Table 5. In the perfect example, if organizations work together, they can create 70 units of payoff. To achieve this payoff, according to Table 6, A must allocate its resources to the creation of a specific service, and B and C must allocate their resources to general services. The distribution of payoffs differs in the perfect example. Interestingly, in two other examples, there is no difference between different methods; this is due to the violation of Assumption 1 and the uniqueness of the answer. In the perfect example, it is possible to have more different distributions due to the establishment of Assumption 1.

6. EXPERIMENTAL EVALUATION

The results of the experiments are presented in this section. We considered four different types of factors. These factors were used according to the opinions of experts to consider a wide range of real cases:

- The number of organizations (n): our goal was to examine the coalition of a small to a large number of organizations. Organizations seek to achieve specific goals or specific interests. The analysis of these interests and their dependencies is more challenging on a larger scale than in a small number of organizations.
- Side effects of service applicants (a): we have examined the impact of up to 10 input edges for each organization. At the very least, when there is only one input edge, the organization is only affected by an upstream organization service.
- Side effects of service providers (p): similarly, we have examined the impact of up to 10 output edges for each organization.
- The ratio between the benefits and costs (r): We have inspected the effect of changing an organization from a specific service provider to a general service provider or *vice versa* and the benefit of its side effects. It has been studied in different modes from 0.1 to 1. The ratio of 0.1 means that the cost/benefit ratio of organizations is at least ten times that of their upstream organizations. The value of 1 means that the cost and benefits are equal.

An algorithm creates a random graph based on the specified parameters and examines the problem conditions. The algorithm was implemented using MATLAB on a system with a Core i7-8650U 1.9 GHz Processor and 16 GB of RAM.

In the first experiment, the number of organizations was examined. The experiment looked at what percentage of the worth of coalition is distributed using the proposed solution. The experiment considers the distribution

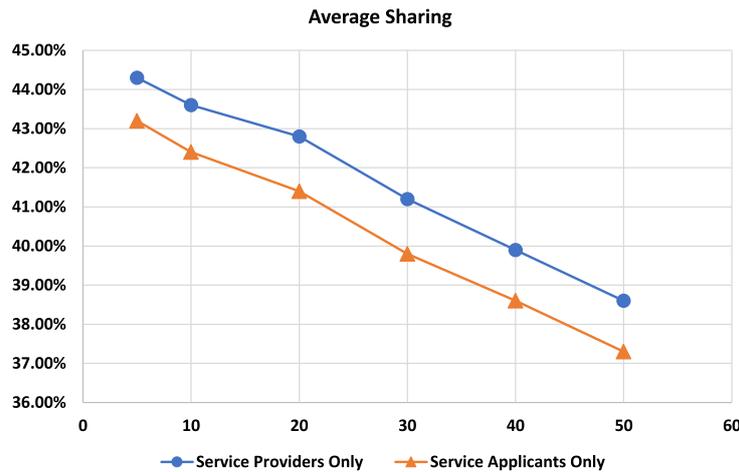


FIGURE 6. The average sharing of the worth of a coalition.

of the worth of coalition between the organizations that are only service providers or only service applicants as the number of organizations involved increases. In this experiment, the average of affected organizations (a and p) was three, and the average ratio of benefits and costs (r) was 0.5. The average of the results is shown in Figure 6. The increase in the number of organizations causes an increase in the value of the coalition. This increase leads to a lower percentage of payoff sharing with service providers. Service applicants also remain in the coalition with a lower percentage of sharing their payoff.

In the second experiment, the outcome of side effects (outgoing and incoming edges) was examined. It was examined how payoff sharing could be affected by the number of side effects of service. The average benefit-cost ratio was considered as 0.5. As Figure 7 shows, the experiment was performed in three steps for a_i and p_e equal to 1, 2, and 3. The results showed that for lower side effects, the increase in the number of organizations decreases the amount of payoff sharing more sharply. This trend becomes more stable with increasing the number of side effects. The results are also affected by the increase in the worth of the coalition. The increase in the number of organizations and their side effects lead to a decrease in payoff sharing. These results indicate that the benefits of organizations in the coalition increase with increasing service delivery.

In the third experiment, the ratio of the average benefits and costs (r) was considered. In other words, the increase in particular service benefits for an organization and its effects on the payoff of the service provider was examined. The average of affected organizations (a and p) was considered equal to 3. Figure 8 shows the results of this experiment. The r ratio was increased from 0.1 to 1. The results showed that when the r increase from 0.1 to 0.5 (five times increase in benefits), the payoff sharing with organizations does not make a significant difference. On the other hand, when the r ratio is equal to 1, the amount of payoff sharing with purely service providers experiences a significant reduction. This difference shows that providing valuable services, despite sharing benefits with other organizations, brings much more to the service applicants.

7. CONCLUSION

In this article, we explored the issue of facilitating the inter-organizational integration of business applications by forming coalitions. We addressed the issue of how organizations can be encouraged to provide specific services needed by other organizations by cooperatively sharing the benefits of delivered services. We have shown that it is possible to apply the cooperative game theory to solve the challenge of reaching the best agreement between organizations. We provide a sustainable way to distribute the benefits of providing specific services of business applications. The benefits of services are shared by forming a coalition between service applicants and service

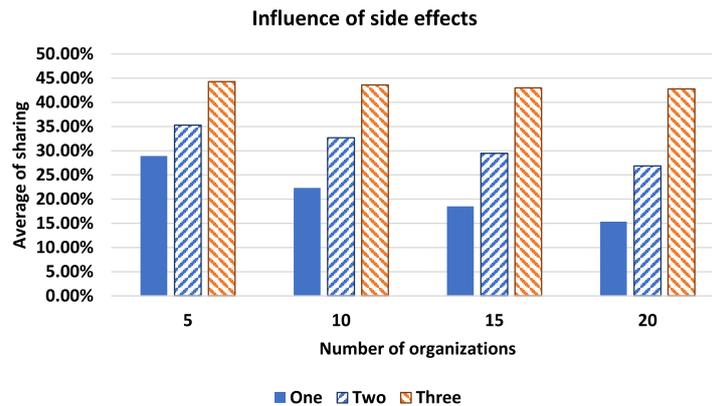


FIGURE 7. Influence of side effects.

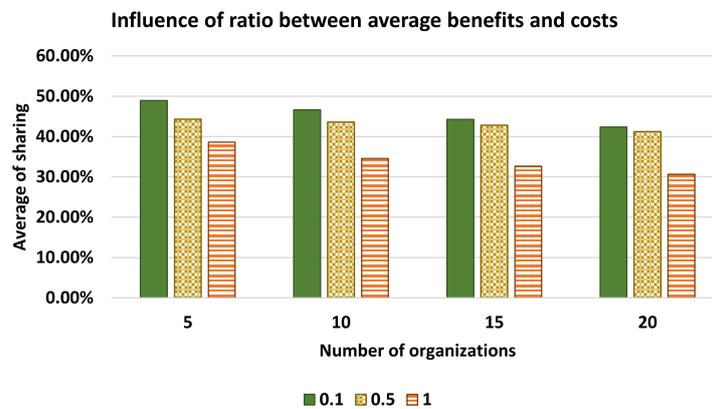


FIGURE 8. Influence of ratio between average benefits and costs.

providers. This sharing is sustainable because leaving this strategy reduces or does not change the payoff of organizations. The results of our experiments considering various factors, including the number of organizations, the side effects, and the ratio of benefits to costs, showed that successful coalition formation is always possible. These experiments determined the extent of benefits distributed between service providers and service users. The results showed that with the formation of coalitions between organizations and increasing the number of provided services, despite the cooperative participation of organizations, the benefits of these organizations will increase.

Our proposed solution helps various public aspects and management strategies. This includes economic aspects (*i.e.*, how to encourage the provision of services), issues related to providing public subsidies (*e.g.*, providing IT industry subsidies or tax exemptions), and including public participation (*e.g.*, ensuring private sector participation).

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