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Optimizing Information Flow in International Trade Transaction

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Abstract. Information transfer procedures often require a particular set of procedures and a wide range of documents that every organization must follow in order to achieve a successful transaction between countries. This issue leads to several problems, including unnecessary expenses, extra processing time, and additional administrating resources. Several researchers have proposed algorithms to reduce the redundancy of information. However, none of the existing algorithms are capable of delivering an optimal information flow of the international transaction. In this paper, a new algorithm is designed under the characteristics of an international trade transaction. The main theoretical contribution of this paper is to develop the algorithm with the concept of the brute-force approach to allow the investigation of all possible flows without information redundancy and chose the optimal one. To show the practical contribution of this paper, a part of the trade transaction between Thailand and Laos P.D.R. is used to show a detailed insight into the algorithm. The document and information flow of the case study are shown and the information redundant is eliminated. The results show that, by using the proposed algorithm, the number of information transfers is lower, and the maximum distance of the information flow is shorter while there is no missing information. They also indicate that the proposed algorithm can reduce redundant information and simplify the networks in international trade.

Keywords: information overproduction, optimal information flow, brute-force approach, lean information

1. Introduction

International trade plays an important role in economic development. In general, trade refers to the exchange of money for goods or services and is called international trade when it is conducted between countries. Many countries consider international trade as a key element to improve their economic growth and stimulate job markets. Developing countries, especially ASEAN countries, successfully export a variety of services to both developed and developing countries (De, 2006). Since the 80's, the concept of globalization has had a major impact on the volume of exported and imported goods, including an expansion of global outsourcing and increase of trade flow, as seen in Fig. 1.

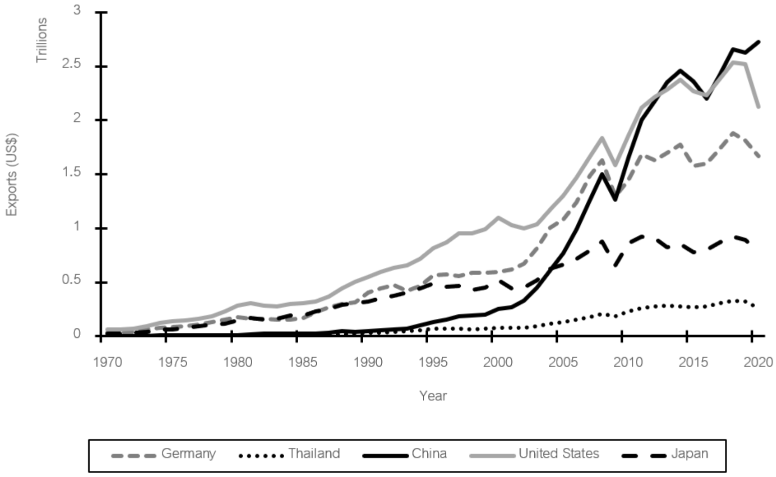


Fig. 1: Exports of goods and services (World Bank, 2022)

International trade, similar to domestic trade, is generally divided into four phases: pre-contractual, contractual, logistics, and post-delivery (Wrigley, 1994). International trade involves transferring goods, information, services, and money that must be processed based on different regulations from different countries. Therefore, it can be more competitive than domestic trade and challenge organizations to be more efficient and cost-oriented. However, there are many problems in international trade, such as unfavorable terms of trade, risk in transit, problems in payment due to different currencies, and difficulty in transportation due to distance and some restrictions. Therefore, it is difficult to manage the process.

To tackle this problem, several nations have established cross-national cooperation and agreements to develop open markets, such as the North America Free Trade Agreement (NAFTA), European Union (EU), or World Trade Organization (WTO). Along with the concept of industry 4.0 that is widely used to help improve efficiency in the process of international trade, the complexity of document flow remains a major challenge (Castagnoli, 2021). Altomonte and Bekes (2010) concluded that the number of documents needed in each country increases the complexity of international trade. A recent study shows that paper-based processes are still common practice in international trade due to the difficulties of implementing the e-document system, such as high investment costs and the many requirements (Civelek, 2017). Two important factors in international trade are customs restrictions and the documentation flow system (Ponanan, 2019; Srichanthamit & Suto, 2020). In many instances, overly complicated regulations and redundant documentation lead to higher costs and unnecessary expenses (Bernal Turnes & Ernst, 2015). Furthermore, different forms of networks add to the complexity of the information flow system. There are several paths in the networks that are controlled by governments under fixed policies and regulations. Therefore, the information networks of international trade cannot be completely redesigned and commonized. In addition, factors such as different languages or documents forms can result in a longer processing time and missing information (Bernal Turnes & Ernst, 2015).

To consider the redundant information in the international trade transaction, Ponanan et al (2019) and Watanabe and Patitad (2022) have proposed an algorithm also to reduce information redundancy. In both pieces of research, redundant information refers to the same information being received several times by the same node. In Ponanan et al (2019), redundant information is eliminated by checking its amount of redundancy. While in Watanabe and Patitad (2022), this information is reduced by checking the information that involves the longest route and terminating it.

As mentioned in the above paragraph, there are some researches that consider redundant information and how to resolve it. Although those algorithms are utilizable, however, the answer from the algorithm is not an optimal solution. Therefore, in this paper, an algorithm to determine an optimal information flow for international trade transactions with the concept of brute-force approach is proposed. The main contributions of this paper are summarized as follows.

- A new algorithm to find an optimal information flow for international trade transactions. With the proposed algorithm, a conservative information flow and decreased distance to receiving the information of each organization in the flow are ensured.
- By the concept of brute-force approach, the algorithm also identifies the optimal solution.
- The case study of the trade transaction between Thailand and Laos P.D.R. is used to show the practical implication of the proposed algorithm.

This paper consists of seven sections. Section 2 introduces the background of information network in international trade and lean information management. An introduction of the model is described in section 3. Section 4 proposes the proposed algorithm to the trade transaction between Thailand and Laos P.D.R. In section 5 and 6, empirical results are summarized and discussed. Section 7 presents the conclusions and limitations of this study.

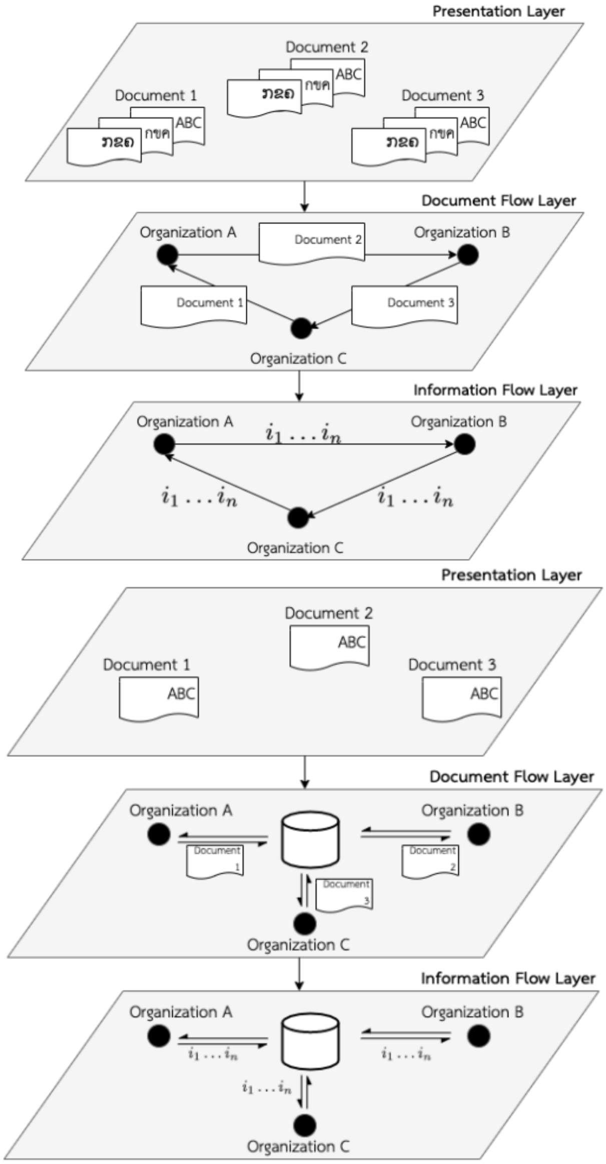
2. Literature Review

2.1. Information Networks in International Trade

International trade involves a great number of activities, people, materials, and documents. Fast, efficient, and reliable communication is a crucial factor in international trade. The movement of information among the participants is considered extremely important because it determines the performance of the system (Sundram et al., 2020). Mismanaged information can lead to both direct and indirect monetary loss, such as a loss in revenue, high operational cost, and opportunity cost (Wrigley, 1994). Ponanan et al. (2019) have proposed a three-layer mode, including a presentation layer, document flow layer, and information flow layer, as shown in Fig. 2. This model has been used in much research, such as for determining the document flow (Srichanthamit & Suto, 2020) and suggesting a suitable information flow (Watanabe & Patitad, 2022). In the presentation layer, information labels are presented in the languages used by each partner. In the document flow layer, the flow of all documents in the process is represented as networks where nodes are destinations and relations are documents. The bottom layer represents information flows.

The e-document system is commonly used in domestic trade. Since each company can pull all the data it needs from a central database, it ensures that everyone will receive the same data. Thus, the redundancy issue in information flow is eliminated. On the other hand, the information system of international trade is more complex (Figure 2a). In the presentation layer, information labels are presented in the multiple languages required by each partner. The specific information is extracted from the corresponding documents to develop networks where information is sent from one node to another.

Several studies have proposed solutions to improve the information and documentation flow in international trade, such as improving accuracy in the information transfer to minimize the work in process (Mukaddes, 2010), implementing IoT and Blockchain to redesign supply networks and improve the supply value (Rejeb, 2019), implementing an e-documents system to reduce the complexity of the documentation flow of international trade (Civelek, 2017; Moon, 2011), and using real-time transit information systems to reduce the waiting time in documentation flows (Liu & Miller, 2020). Therefore, reducing the complexity of the documentation flow and a number of redundant documents in international trade can help improve the ease of doing business, especially in the complex networks in international trade.



(a) International trade transaction model (b) Domestic trade transaction model (Adapted from Watanabe & Patitad (2022)) with e-document

Fig. 2: Comparison of international and domestic transactions

2.2. Lean Information Management

The principle of lean management is focused on eliminating waste. It is widely used, especially in the manufacturing process. To simplify processes by eliminating waste, speeding up response times, and reducing the workforce can lead to an improvement in information flows (Redeker, 2019). Even though lean management is a generic concept that can be applied to many systems, implementing lean management in information management remains a major challenge (Müller, 2017).

Since the flow of the information system in international trade contains several crucial elements, it is prone to inefficiency and mismanagement. For example, international trade that involves three different partners requires similar information in different languages and forms. This results in weeks of processing time and high operational costs.

The concept of lean information management is used to mitigate these issues. To achieve lean information management, it is crucial to identify waste and redundant information through improving the management of sources of information, improving the information management in business processes, assessing and improving the information system infrastructure (Hicks, 2007).

3. Methodology

The proposed algorithm for optimizing information flow contains three main steps; 1) convert document flows to information flows, 2) eliminate redundant information, and 3) select the optimal information flow.

3.1. Converting Document Flows to Information Flows

The first step is the same as the step which is used by Srichanthamit & Suto (2020) and Watanabe & Patitad (2022). To illustrate the conversion of document flows into information flows, a graph structure is used. In the structure, nodes denote the organizations and lines indicate the path of the documents or information.

The process in an international trade named X is described as $P^X = (\mathbb{D}^X, \mathbb{G}^X)$, where D^x is a set of documents used in process *X*, and G^x is a structure of the process *X*. In a document *a* in process *X*, $D^a(\in \mathbb{D}^X)$, there is a set of information which is described as $D^a = \{i_1, i_2, \ldots, i_m\}$, where $i^m(\in D^a)$ represents information m included in the document a.

A document can be considered as set of information. Therefore, all the information in the document has the same structure as that particular document. Moreover, there are also some information elements that are presented in several documents. Consequently, we can generate a structure of the information, from the structure of the documents that contain that information, using the following equation:

$$G^m = \{ \bigcup_{D^a \in \mathbb{D}^X} \mathbb{G}^a | \, D^a \cap \{i^m\} \neq \varnothing \}$$

Where,

G^m : a network structure of information *m*.

3.2. Eliminating Redundant Information

The information flow will be verified to identify whether there is any redundant information by using Algorithm 1 (Fig. 3).

In this step, it starts with creating a set of reachability paths of information (P) which contains reachability path (P_l). Then a set of the transitive closure of reachability paths of information (P_i), which contains the transitive closure of reachability path (P), is generated (Lines 4–5). Each reachability path and its transitive closure is a set of paths from the source node U_i to the destination node U_j $\{(U_i, U_i)\}$. The transitive closure of each path is checked to identify redundant information.

Algorithm 1 Checking for redundant information

1: **procedure** CheckredundantInformation(G)
2: **Input** G : Graph
3: **Output** G^* : Graph G after reducing information redundant
4: Create a set of reachability path $\mathbb{P} = \{P_1, P_2, ..., P_L\}$
5: Create a set of transitive closure of reachability path $\mathbb{P}' = \{P'_1, P'_2, ..., P'_L\}$
6: **if** $\bigcap_{l=1}^{L} P'_l \neq \emptyset$ **then** ▷ If there is any redundancy
7: $\mathbb{G}$ = CheckPath(G)
8: G^* = ChooseGraph($\mathbb{G}$)
9: **end if**
10: **return** G^*

Fig. 3: Pseudo code of checking for redundant information algorithm

As mentioned in the previous section, information that travels along more than one path to the same destination is considered as redundant. To eliminate this redundancy, an algorithm for this step is shown in Fig. 4. In this algorithm, each path of the information l is chosen and compared with the other path k. If there is a redundant path, the redundant path will be kept. After that, all the redundant paths will be compared. The longest path will be identified as D (lines 14–17) and eliminated (lines 20–21). This algorithm will be repeated until there is no redundant path remaining. This can be verified by using a recursive function. All possible information flows will be kept as a set of graphs G (line 21). The result from this step is the set of all possible information flows, from which all redundant information is eliminated.

3.3. Selecting the Optimal Information Flow

After eliminating all the redundant information, all feasible information flows are generated. After that, the distance of the flow (from the origin node to the destination node) of each flow is calculated. The distance represents the time it takes for all nodes to receive the information. Therefore, the information flow that has the shortest distance is the optimal information flow. This workflow is represented using Algorithm 3 which is shown in Fig. 5. This algorithm ensures that information flows with the shortest length of the longest path will be selected.

Algorithm 2 Eliminating redundant information

procedure Elimination(G)
Input G : Graph
Output $\mathbb{G}$: Set of possible graphs which creating from reducing redundant information in graph G
  Create a set of reachability path $\mathbb{P} = \{P_1, P_2, ..., P_L\}$
  Create a set of transitive closure of reachability path $\mathbb{P}' = \{P'_1, P'_2, ..., P'_L\}$
  $SizePath = 0, D = \emptyset, \mathbb{G} = \emptyset$
  for $l = 0; l \leq |\mathbb{P}| - 1; l++$ **do** ▷ Choose path l to delete
    for $k = 0; k \leq |\mathbb{P}| - 2; k++$ **do** ▷ Compare with path k
      if $P'_l \cap P'_k \neq \emptyset$ **then** ▷ If there is any redundancy in path l with path k
        $P^*_k = \{e|(v'_i, v'_j) \in P'_l \cap P'_k, (v_i, v_j) = \Phi(e), \exists(e) \in P_l, v'_j = v_j\}$
      end if
    end for
    for $\forall P^*_k$ **do**
      if $|P^*_k| \geq SizePath$ **then** ▷ Find longest path that can delete
        $D \leftarrow P^*_k$
        $SizePath \leftarrow |P^*_k|$
      end if
    end for
    if $D \neq \emptyset$ **then** ▷ If there is path that can be deleted
      $P^*_l \leftarrow P_l - D$ ▷ Delete
      $G_l \leftarrow \{G - P_l\} \cup P^*_l$ ▷ Create new graph
      $\mathbb{G} \leftarrow \mathbb{G} \cup \{\text{CheckPath}(G_l)\}$
    end if
  end for
  return $\mathbb{G}$

Fig. 4: Pseudo code of eliminating redundant information

Algorithm 3 Selecting Optimal Information Flow

procedure SelectOptimalGraph($\mathbb{G}$)
Input $\mathbb{G}$: Set of graphs
Output G^* : Graph with the shortest of the longest path of graphs in $\mathbb{G}$
  $Min = \infty, G^* = \emptyset$
  for $i = 0; i \leq |\mathbb{G}| - 1; i++$ **do**
    if $ev(G_i) \leq Min$ **then** ▷ Choose graph with the shortest of the longest path
      $G^* \leftarrow G_i$
      $Min \leftarrow ev(G^*)$
    end if
  end for
  return G^* ▷ Return graph with the shortest of the longest path among all graphs

Fig. 5: Pseudo code of selecting an optimal information flow

4. Case study

This paper used a case study developed by Klairung et al. (2019) to demonstrate the proposed algorithm. In this example, four types of documents are transferred among seven organizations. The network consists of (1) a seller (v_1), (2) a customs broker of origin (v_2), (3) a customs header of origin (v_3), (4) a freight forwarder (v_4) (5) a customs header of destination (v_5), (6) a customs broker of destination (v_6) and (7) a buyer (v_7). Four types of documents, including a commercial invoice (D^1), packing list (D^2), bill of lading (D^3), and forwarding instructions (D^4), are used in the case study. The details of the documents and their flows are explained in Table 1 and Fig. 6.

4.1. Numerical Example

The information 'Item_Package' from the documents 'commercial invoice' and 'packing list' are used to illustrate the application of the proposed algorithm.

4.1.1. Converting document 'commercial invoice' and 'packing list' to information flow

The flow of these two documents is shown in Fig.7a. In the commercial invoice, there are three information elements described as;

$$D^1 = \{i_1, i_2, i_3\}$$

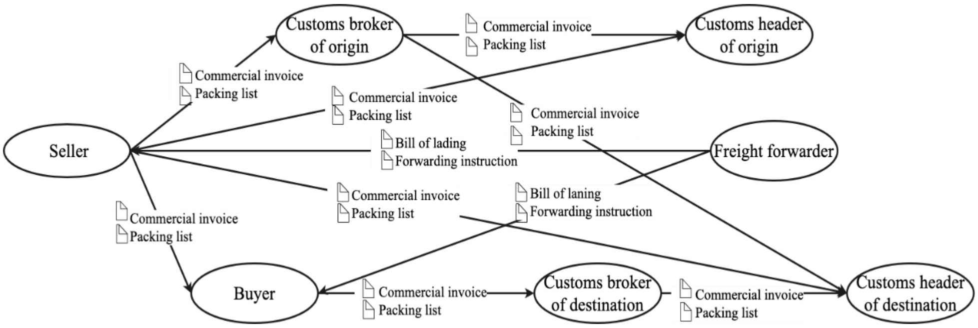
Equivalent to the document D^2, it can be described as;

$$D^2 = \{i_1, i_2\}$$

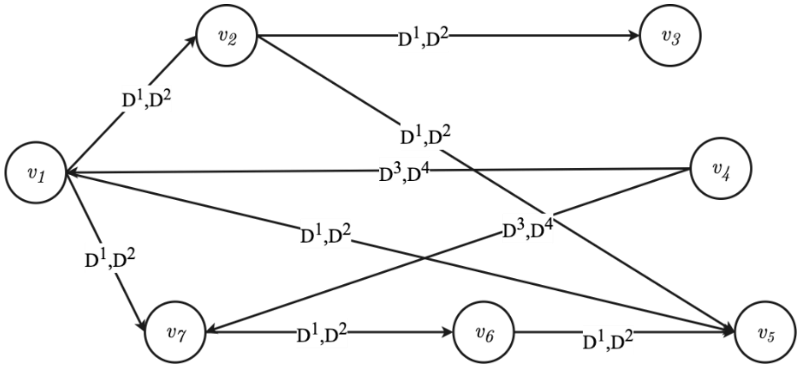
Based on the flow of documents, a flow of information can be generated by using Equation 1, which is shown in Fig. 7b.

Table 1: Documents and information used in the case study

Document	Information	Notation
Commercial invoice	Import Company_Trader[Name,Address] Item_Package Set of Item_ItemGroup [ID$_{No.}$]	i_1 i_2 i_3
Packing list	Import Company_Trader[Name,Address] Item_Package	i_1 i_2
Bill of lading	Import Company_Trader[Name,Address] Trailer_Vehical [License]	i_1 i_4
Forwarding instructions	Import Company_Trader[Name,Address] Item_Package[Size]	i_1 i_5

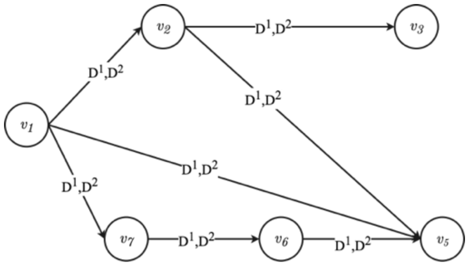


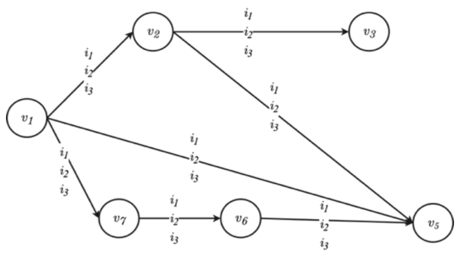
(a) Document flow



(b) Document flow represented by the notation

Fig. 6: Document flow of the case study

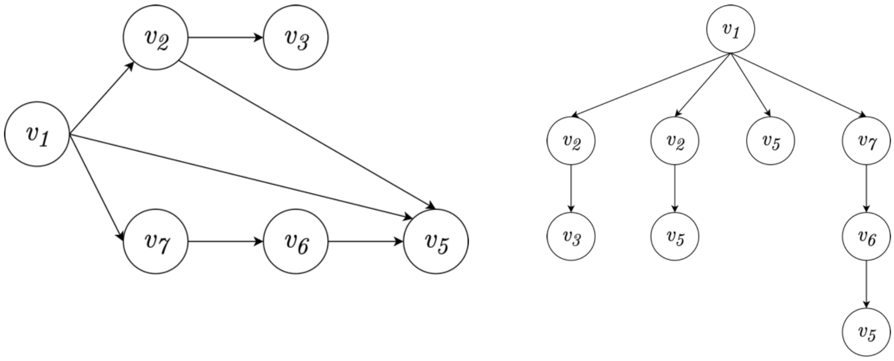




(a) A document flow (b) An information flow

Fig. 7: Structure of document flow and information flow of the documents ‘commercial invoice’ and ‘packing list’

As mentioned above, the information ‘Item_Package’ is used to explain the proposed algorithm. The flow of this information is shown in Fig. 8a.



(a) A flow of information i_1 (b) Reachable path of i_1

Fig. 8: Flow and reachability paths of information 'Item_Package'

4.1.2. Eliminating Redundant Information 'Item_Package'

In the first step, a set of reachability paths of information 'Item_Package' is created from its flow. The reachability paths of this information are demonstrated in Fig. 8b.

A set of reachability paths of information i_1, $\mathbb{P}^1$, and a set of transitive closures of reachability paths of information i_1 and $\mathbb{P}'^1$ are created using Algorithm 1. The result is as below.

$$\mathrm{P}^1 = \{P_1, P_2, P_3, P_4\}$$

$$P_1 = \{(v_1, v_2), (v_2, v_3)\}$$

$$P_2 = \{(v_1, v_2), (v_2, v_5)\}$$

$$P_3 = \{(v_1, v_5)\}$$

$$P_4 = \{(v_1, v_7), (v_7, v_6), (v_6, v_5)\}$$

$$\mathrm{P}^{a} = \{P_1^0, P_2^0, P_3^0, P_4^0\}$$

$$P_1^0 = \{(v_1, v_2), (v_1, v_3), (v_2, v_3)\}$$

$$P_2^0 = \{(v_1, v_2), (v_1, v_5), (v_2, v_5)\}$$

$$P_3^0 = \{(v_1, v_5)\}$$

$$P_4^0 = \{(v_1, v_5), (v_1, v_6), (v_1, v_5), (v_7, v_6), (v_7, v_5), (v_6, v_5)\}$$

Then, redundant information is examined by using the concept of transitive closure. If there is redundant information, Algorithms 2 and 3 are performed. Conversely, if there is no redundant information, the process is finished. In this example, the sets of transitive closure show redundant information (v_1,v_5) in three path. Therefore, these paths are selected and Algorithms 2 and 3 are performed.

In this step, all possible information flows from which redundancy is eliminated are created. Each path in the flow is chosen for comparison with others to determine whether there is a redundant path. If there is any redundancy, it will be eliminated. This process is repeated for each selected path until there is no remaining redundant information.

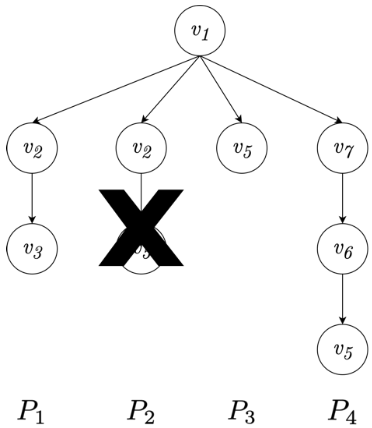


Fig. 9: The longest path that can be eliminated from P_2

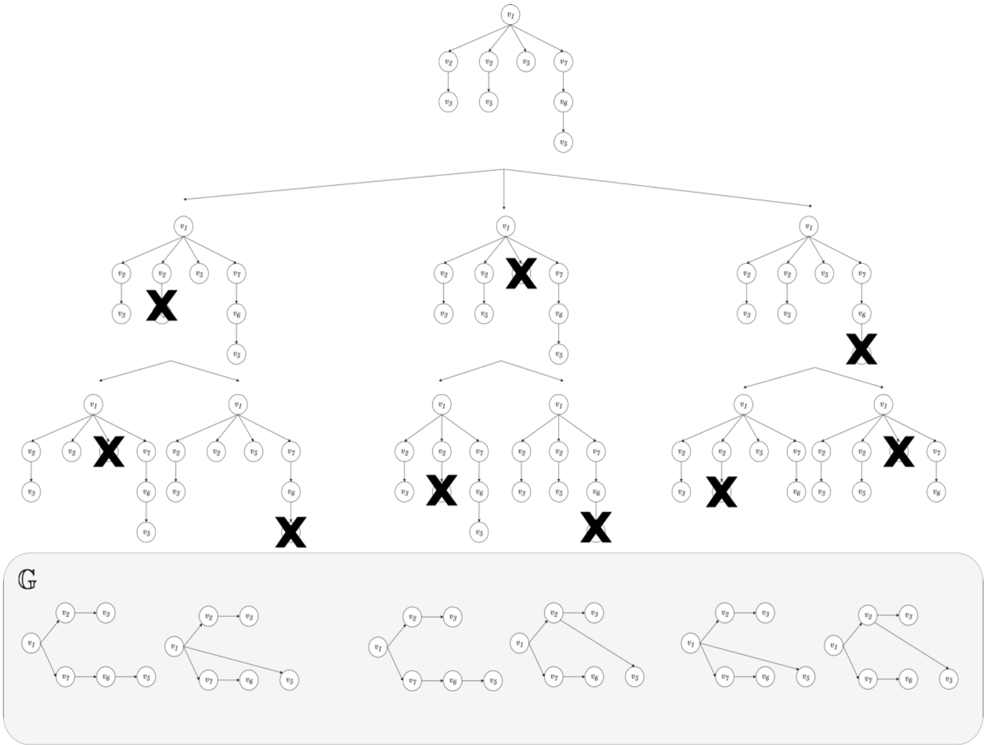
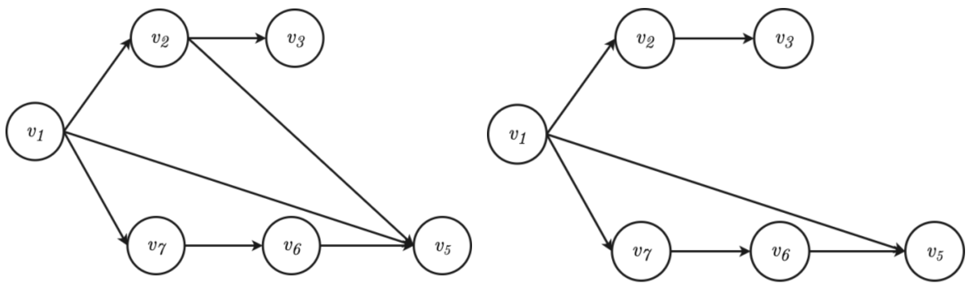


Fig. 10: The set of all possible information flows after eliminating redundancy ($\acute{\mathbb{G}}$)

Based on the example, P2 is selected to be Pl and compared with other paths (P3 , P4). The redundant information {(v2,v5)} is eliminated from P2 as shown in Fig. 9. After that, the recursive function is performed until there is no redundant information left. The set of all possible reachability paths and graphs ($\acute{G}$) of this example is shown in Fig. 10.

4.1.3. Selecting the optimal information flow

After getting all possible information flows, in this step, the optimal information flow is chosen by its dimension. In this example, there are six flows in $\acute{G}$. Firstly, the first possible information flow is chosen to determine its dimension. The dimension of this flow is three. Then this flow is updated to be the optimal flow. Then the second flow is determined for its dimension and compared with the optimal flow. The second flow's dimension is two, so the second flow becomes the optimal flow. The steps are repeated until all flows are chosen. The optimal flow of the information 'Item_Package' is shown in Fig. 11a.

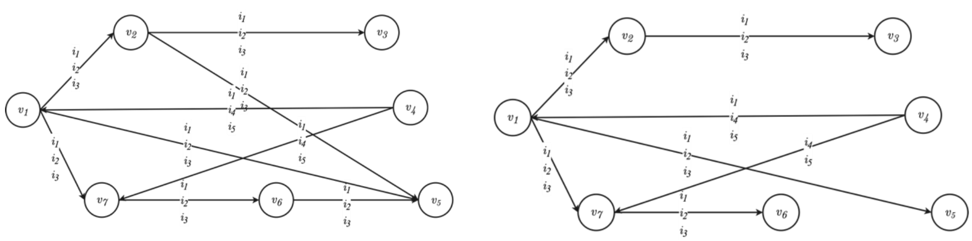


(a) An original flow information i_1 (b) The optimal flow of information i_1

Fig. 11: Comparison of original and optimal flows of information i_1

5. Result

In the previous section, the information flow of information i_1 was used to illustrate the application of the proposed algorithms. The same procedures were executed on the other information flows in the network. Fig. 12 illustrates the optimized information flow compared to the original one.



(a) An original flow information i_1 (b) The optimal flow of information i_1

Fig. 12: Comparison of original and optimal flows of the numerical example

To evaluate the result of the proposed algorithm, the number of information transfers, the dimension of the information flow, and the average length of paths are used as indicators. The result from the proposed algorithm is compared with the results of the original flow and the algorithm developed by Ponanan et al. (2019) and Watanabe & Patitad (2022) (Table 2). The number of information transfers shows how many times the information is sent from one node to another, while the dimension of the information flow represents the longest length that the information travels. The average length of paths in the flow describes the average distance of all information that is delivered to all organizations. These indicators are often considered as overproduction and motion wastes according to lean information management. And the last indicator is if the flow satisfies the optimal solution or not.

Table 2: Comparison results

	Original information flow	Information flow by Ponanan et al. (2019)	Information flow by Watanabe & Patitad (2022)	Information flow by the proposed algorithm
Number of information transfers	48	20	20	20
Dimension of the information flow	3	3	2	2
Average length of paths	1.67	1.67	1.4	1.4
Satisfied optimal flow	no	no	no	yes

After eliminating redundancy in the information flow by using the proposed algorithm, the number of information transfers is decreased from 48 to 20 without any loss of information. The flow using the proposed algorithm is also the most favorable flow, chosen from all possible flows. Similar to the maximum distance of the flow, the results show that the number is decreased from 3 to 2, with the same results from Watanabe & Patitad (2022). The average length of all paths in the information flow of the original flow, the reduced information flow by Ponanan et al. (2019), by Watanabe & Patitad (2022), and by the proposed algorithm are 1.67,1.67, 1.4, and 1.4 respectively.

6. Discussion

From Table 2, the result show that all three algorithms can reduce the number of information transfers to 20, while the algorithm by Watanabe & Patitad (2022) and the proposed algorithm perform better in reducing the maximum distance of the flow and average length of the path in the flow. Assuming that the time spent transferring information is equal in every path, it is clear that using the algorithm by Watanabe & Patitad (2022) and the proposed algorithm can accelerate the process and the information travels faster.

The algorithm proposed by Watanabe & Patitad (2022) and the proposed algorithm is discussed due to their same results from the first three indicators. Only different is the proposed algorithm can determine the optimal flow, the algorithm proposed by Watanabe & Patitad (2022) cannot. The difference between the two algorithms is in how to create the information flow. In the algorithm proposed by Watanabe & Patitad (2022), the flow is created by checking the longest path for any redundancy. If there is any redundancy in a part of the path, that part is eliminated. Meanwhile, the proposed algorithm is allowance to explore all possible information flow after reduce redundancy. These flows are created and the flow with the shortest dimension is chosen. By doing this, the answer from the proposed algorithm is always optimal.

From a theoretical perspective, the algorithm to identify an optimal information flow for international trade transactions is proposed with the concept of the brute-force approach. In the proposed algorithm, the document flows are transferred into the information flows. The graph is used to describe the flows. By applying the brute-force approach, a set of all possible information flow that already eliminated information redundancy is investigated. The optimal information flow is chosen from the set. The step can guarantee optimal flow by listing all the possible candidate solutions for the problem.

From a practical perspective, the proposed algorithm is applied to actual international trade. The trade transaction between Thailand and Laos P.D.R. is brought as a case study. This novel contribution provides a detailed insight into the algorithm. The result shows that, in comparison with the original flow, the information transfer is decreased, and the average distance of the information flow is lower while ensuring the reliability of the flow.

7. Conclusion

There are many complexities and limitations in international trade. To improve the process of international trade, time is a crucial element. Fast information transfer and simple documentation flow will accelerate the process. However, the information flow cannot be completely re-designed due to the different regulations or languages in different countries. To improve the process, as in the previous studies, all the documents required in the process and all information is transformed into information flows. In this paper, the algorithm was proposed under the limitation of the characteristics of the transaction. By using the proposed algorithm, at all nodes it is confirmed that no information is missing. The processing time is also proved to be faster due to the lower numbers of information transfers, shorter dimension of the flow, and shorter average length of path in the flow. The result shows that the proposed algorithm can reduce redundant information in international trade and simplify the networks optimally.

The limitation of the proposed algorithm is its generality, due to the fact that it is designed under the characteristics of international trade transactions. Also, in the proposed algorithm, all possible solutions are created. For large-scale networks, this may cause time-consuming assessment.

For further research, it will be meaningful to adapt this proposed algorithm to be applicable in an environment that includes many forms of network, creating many obstacles and limiting the opportunities for re-designing the information flow system.

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