国際貿易取引における事務処理効率化支援システムの構築

A Supporting System for Improving Efficiency of Paperworks in International Trade Transaction Processes

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Declaration

I hereby declare that this thesis is my own work and effort and that it has not been submitted anywhere for any award. Wherever contributions of others are involved, every effort is made to indicate this clearly, with due reference to the literature, and acknowledgement of collaborative research and discussions.

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Abstract

In this study, a supporting system for improving efficiency of paperworks in international trade transaction processes is proposed. Then, the performance of the proposed system is investigated by conducting experiments.

International trade transaction process between different countries has an important role in economic developments and movement of goods, service, and technology. Usually, each country designs its own transaction processes without considering other countries' circumstances. That is to say, international trade transaction processes can be considered as systems consisting of sub-systems designed by each country based on their own concepts and policies. This fact makes international trade transaction systems complex. Of course, if we can reconstruct the whole-system, we can reduce the redundancies and make it more efficient. However, it is not easy to reconstruct the complex integrated system with keeping the consistency.

To solve the problem, a system for reducing redundancies of paperworks in international trade transaction processes is developed. The basic idea is shown below:

(1) Describe the target international trade transaction processes as a network structure. Here, each node stands for an organization, and each edge stands for a flow of document.
(2) Convert the network structure to another network structure which stands for information.
(3) Reduce the information flows by eliminating redundant edges.
(4) Convert the information flow to document flows.

For example, a network in Fig. 1 (A) shows an example of document flow in a part of an international transaction process.

The network structure of the example is described as $\mathbb{G} = (\mathbb{V}, \mathbb{E})$. Here, $\mathbb{V}$ stands for a set of nodes which represent organizations in a process and $\mathbb{E}$ stands for a set of edges which represent a path of document flows in a process.

Organizations of the example can be described as $\mathbb{V} = \{\mathrm{v}_1, \mathrm{v}_2, \mathrm{v}_3, \mathrm{v}_4, \mathrm{v}_5\}$. A path of

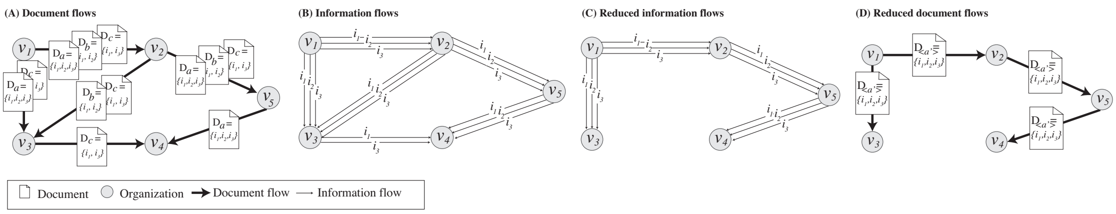

Figure 1 – An example of information flow

document flows in a process can be described as $\mathbb{E} = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_1, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_3), (\mathrm{v}_3, \mathrm{v}_4), (\mathrm{v}_2, \mathrm{v}_5), (\mathrm{v}_5, \mathrm{v}_4)\}$. The routes of the documents can be described as $\mathrm{R}^{\mathrm{d}}_a = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_1, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5), (\mathrm{v}_5, \mathrm{v}_4)\}$, $\mathrm{R}^{\mathrm{d}}_b = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_2, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5)\}$, $\mathrm{R}^{\mathrm{d}}_c = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_1, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5), (\mathrm{v}_3, \mathrm{v}_4)\}$.

These routes of documents can be converted to routes of informations by using the below formula.

$$\mathrm{R}^{\mathrm{i}}_m = \{ \bigcup_{\mathrm{D}_p \in \mathbb{D}_X} \mathrm{R}^{\mathrm{d}}_p |\, \mathrm{D}_p \cap \{\mathrm{i}_m\} \neq \phi\} \tag{1}$$

where, D_p stands for a document p, $\mathbb{D}_X$ stands for a set of documents used in a process X, $\mathrm{R}^{\mathrm{d}}_p$ stands for a route of document p, i_m stands for an information m, and $\mathrm{R}^{\mathrm{i}}_m$ stands for a route of information m.

Figure 1 (b) shows the results; $\mathrm{R}^{\mathrm{i}}_1 = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_1, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5), (\mathrm{v}_3, \mathrm{v}_4), (\mathrm{v}_5, \mathrm{v}_4)\}$, $\mathrm{R}^{\mathrm{i}}_2 = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_1, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5), (\mathrm{v}_5, \mathrm{v}_4)\}$, $\mathrm{R}^{\mathrm{i}}_3 = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_1, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5), (\mathrm{v}_3, \mathrm{v}_4), (\mathrm{v}_5, \mathrm{v}_4)\}$.

Next, the information flows are reduced as following way:

(1) Find a node which has the maximum number of in-degree.
(2) Find all sender nodes that link to the node found in step (1).
(3) Find the maximum number of out-degree of sender nodes.
(4) An edge that connects to the sender node and the receiver node is eliminated.
(5) From (2) to (4) are repeated until all nodes have the number of in-degree less than one.

By following the procedure, the network shown in Fig. 1 (b) is changed as: $\mathrm{R}^{\mathrm{i}}_1 = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_1, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5), (\mathrm{v}_5, \mathrm{v}_4)\}$, $\mathrm{R}^{\mathrm{i}}_2 = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_1, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5), (\mathrm{v}_5, \mathrm{v}_4)\}$, $\mathrm{R}^{\mathrm{i}}_3 = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_1, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5), (\mathrm{v}_5, \mathrm{v}_4)\}$. Figure 1 (C) shows the network structure of the reduced information flows.

Then, document flows are generated from the reduced information flows with the following procedure:

(1) Documents which include only one information are created. Eventually, the number of documents become same as the number of informations in the process. Each document has the same route with information which included in the

Table 1 – The numbers of information transmission of current process and the reduced process in the example

Original process of example			
Document	Number of informations	Times of document transmission	Total number of transmission
D_a	3	4	12
D_b	2	3	6
D_c	2	5	10
Total number of information Transmission of all documents			28

Reduced process of example			
Document	Number of informations	Times of document transmission	Total number of transmission
D'_a	3	4	12
Total number of information Transmission of all documents			12

document.

(2) Find a pair of documents which can be merged together because they have a common part in the paths.

(3) If there are a pair of documents, they are merged, otherwise finish.

(4) Repeat (2) - (3).

As a result, a reduced document flow shown in Fig. 1 (D) is obtained. Table 2 shows number of documents and number of transmitting documents in the original process and reduced process. As we can see from the table, total number of documents has reduced from three to one (66.6%), and the total number of transmitting documents has reduced from twenty-eight to twelve (57.2%).

Here, many kinds of redundancies, e.g. (1) redundancy of sharing information and (2) redundancy of using documents are considered, and these redundancies have a trade-off relationship. Thus, in the actual situation, we have to decide which redundancy should be focused on. The proposed system can show some solution candidates with the evaluation values which show several types of redundancies. Therefore, the proposed system can be applied for various situations.

Examples of international trade transaction processes in ASEAN countries are shown to discuss the abilities of the proposed system. As a result, it became clear that the proposed system can be applied for relatively huge-sized problems. In the system, synchronizing multi-document transitions and permission control of information are not considered. In order to implement actual system based on the idea, these problems must be solved in the future.

概要

本稿は，国際貿易取引における事務処理の効率化を支援するシステムを提案し，実験結果を示してによってその効果を明らかにするものである． 国際貿易取引は，サプライチェーンのグローバル化により，その重要性を増している．一般的に国際貿易取引のための事務処理は複雑かつ冗長性が高いと考えられている．その理由は，各国が独自に設計した海外との貿易の仕組みの組み合わせとして全体のシステムが構成されていることが考えられる．あらためてシステム全体を再設計することで効率化が期待できるが，すでに複雑に絡み合っている事務処理を最適な形に近づけることは容易ではない．また，一概に事務処理の効率化といっても，書類の数，1種類の書類に含まれる情報の数，1種類の書類の経路とさまざまな視点があり，それぞれの基準から最適な状態が異なるという難しさがある． そこで本研究では，国際貿易取引における事務処理による情報の流れをネットワーク構造で記述し，効率化アルゴリズムでサイズを縮小することによって，同じ情報伝達機能をもったより小さなネットワークを生成することで，事務処理の効率化を行う．具体的な手順を下に示す．

(1) 国際貿易取引における事務処理をネットワーク構造で記述する．このとき，ノードを事務手続きに関わる組織，エッジを文書の流れとする．
(2) 記述した文章の流れを表すネットワークを，情報の流れを表すネットワークに変換する．
(3) 情報の流れを表すネットワークから冗長なエッジを削除する．
(4) 冗長なエッジを削除した情報の流れを表すネットワークを文書の流れを表すネットワークに変換する．

Figure 2に示す例を用いて，この手順の概要を説明する． Figure 2(A)に示すネッ

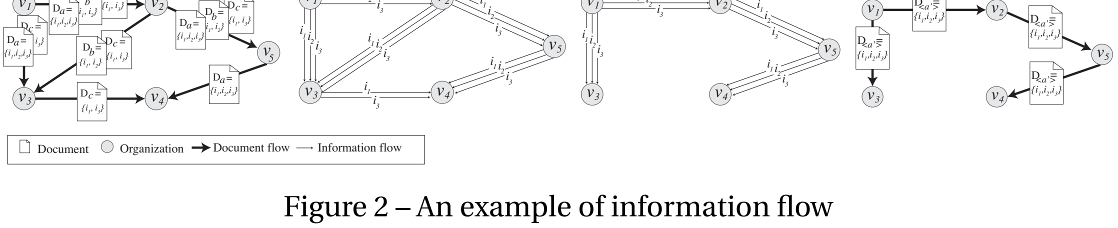

Figure 2 – An example of information flow

トワークはある国際貿易取引における文書の流れの一部を表している． このネットワークを$G = (\mathbb{V}, \mathbb{E})$とすると，$G$は次のように記述できる． $\mathbb{G} = (\mathbb{V}, \mathbb{E})$, $\mathbb{V} = \{\mathrm{v}_1, \mathrm{v}_2, \mathrm{v}_3, \mathrm{v}_4, \mathrm{v}_5\}$, $\mathbb{E} = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_1, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_3), (\mathrm{v}_3, \mathrm{v}_4), (\mathrm{v}_2, \mathrm{v}_5), (\mathrm{v}_5, \mathrm{v}_4)\}$.

また，文書pの流れを$\mathrm{R}^{\mathrm{d}}_p$と表すとき，$G$中の文書の流れは次のように記述できる．
$\mathrm{R}^{\mathrm{d}}_a = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_1, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5), (\mathrm{v}_5, \mathrm{v}_4)\}$, $\mathrm{R}^{\mathrm{d}}_b = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_2, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5)\}$, $\mathrm{R}^{\mathrm{d}}_c = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_1, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5), (\mathrm{v}_3, \mathrm{v}_4)\}$. このとき，式(2)を用いて，文章の流れを情報の流れに変換することができる．

$$\mathrm{R}^{\mathrm{i}}_m = \{\bigcup_{\mathrm{D}_p \in \mathbb{D}_X} \mathrm{R}^{\mathrm{d}}_p | \, \mathrm{D}_p \cap \{\mathrm{i}_m\} \neq \phi\} \tag{2}$$

Figure 2 (b)にその結果を示す（$\mathrm{R}^{\mathrm{i}}_1 = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_1, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5), (\mathrm{v}_3, \mathrm{v}_4), (\mathrm{v}_5, \mathrm{v}_4)\}$, $\mathrm{R}^{\mathrm{i}}_2 = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_1, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5), (\mathrm{v}_5, \mathrm{v}_4)\}$, $\mathrm{R}^{\mathrm{i}}_3 = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_1, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5), (\mathrm{v}_3, \mathrm{v}_4), (\mathrm{v}_5, \mathrm{v}_4)\}$).

次に下の手順に従って，冗長なエッジを削除する．

(1) 最大の入次数（in degree）をもつノードを探す．
(2) そのノード入っているエッジで直接繋がっているノードを探す．
(3) それらの中から最も大きな出次数（out degree）を持っているノードを探す．
(4) (2)で見つかったノードと3で見つかったノードの間のエッジを削除する．
(5) 全てのノードの入次数が1になるまで，(2)から(4)を手順を繰り返す．

この手順によって，Fig. 1 (b)に示すネットワークは次のように縮小される． $\mathrm{R}^{\mathrm{i}}_1 = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_1, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5), (\mathrm{v}_5, \mathrm{v}_4)\}$, $\mathrm{R}^{\mathrm{i}}_2 = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_1, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5), (\mathrm{v}_5, \mathrm{v}_4)\}$ $\mathrm{R}^{\mathrm{i}}_3 = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_1, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5), (\mathrm{v}_5, \mathrm{v}_4)\}$. Figure 2 (C) はこの情報の流れを図示したものである．

次に，この縮小された情報の流れを，下に示す手順によって書類の流れに変換する．

(1) 情報が1つだけ含まれた書類群を作成する．つまり，情報の数だけ書類が作成される．それらの書類の流れは，それに含まれる情報の流れと同じであるようにする．
(2) 経路の重複があり，統合可能な書類のペアを1つ探す．
(3) ペアが見つかった場合は，これらを統合して1つの書類にする．ペアが見つからない場合は終了する．
(4) 手順(2)-(3)を繰り返す．

この手順によって，Fig. 2 (D) に示す書類の流れが得られる． Table 2は，元のプロセスと縮小化後のプロセスとに含まれる書類の数と，書類の受け渡し回数を表したものである． この表から分かるように，提案手法によって，文章の数は3から1へ（66.6%），書類受け渡し回数は28から12へ（57.2%），それぞれ減少した．

事務手続きの効率性については，（1）不要な情報の受け渡し，（2) 必要な書類の種類の数など，さまざまな視点からこれを考えることができる． そして，これらは一種のトレードオフの関係にあり，たとえば必要な書類の種類を減らせば，1種類の書

Table 2 – The numbers of information transmission of current process and the reduced process in the example

Original process of example				Reduced process of example			
Document	Number of informations	Times of document transmission	Total number of transmission	Document	Number of informations	Times of document transmission	Total number of transmission
D_a	3	4	12	D'_a	3	4	12
D_b	2	3	6	Total number of information Transmission of all documents			12
D_c	2	5	10				
Total number of information Transmission of all documents			28				

類に含まれる情報が増えてしまうことから，不要な情報の受け渡しの可能性が高まることになる． よって，冗長性の削減について考える場合には，状況に応じた対策が必要になる．提案手法は，複数の解候補を，複数の観点からの評価値とともに提示することが可能であり，さまざまな状況に適応することが可能である．

論文では，ASEAN諸国間の国際貿易事務処理を例に，提案システムの有効性について議論した．その結果，提案手法は，比較的大規模な問題に対しても問題無く適応できることが分かった． 提案システムは，複数の組織間での事務手続きの時間的な同期や，情報へのアクセス権限については考慮していない．実際の問題に適応するため，これらの問題の解決が今後の課題になる．

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1 Introduction

This chapter provides an introduction to the research covered in this study. It starts by explaining backgrounds of the study, followed by purpose of thesis and research contributions. Then, details of the structure of thesis is shown.

1.1 Background of the study

In recent years, international trade processes between different countries have an important role in the economic development and movement of goods, services, and technology. Regional economic integration occurs to remove barriers of trading and customs unions between countries. For instance, the European Union (EU) is the regional economic integration in the Europe zone which aims to remove barriers to trade such as tariffs and border controls. In Southeast Asia, it also has the regional economic integration Association of Southeast Asian Nations (ASEAN). One of the aims of ASEAN is to accelerate economic growth, social progress, and cultural development. In the North America zone, the U.S., Canada, and Mexico, there is the NAFTA which aims to eliminate or reduce barriers to trade and investment. Although the aims of each regional economic integration are successful, limitations of international trade have remained. For example, each country has designed its own international trade transaction processes without considering other countries' circumstances.

Therefore, international trade transaction processes can be considered as systems consisting of sub-systems designed by each country for international trades. Thus, each sub-system has designed based on their own concept, and it makes the whole-system complex. If we can reconstruct the whole-system, it could be a higher efficient system. However, it is not easy to reconstruct the complex integrated system with keeping the consistency. Despite many countries try to reduce the complexity of documentation requirements in the process of trading across borders, e.g. developing online submitting system and sharing their regulations on the Internet [1, 2], the problems have not resolved yet. Such facts cause several types of redundancy of paperworks process in an international trade transaction, such as redundancy of sharing information and redundancy of using documents.

To solve the problems, a system for reducing redundancy of paperworks in international trade transaction processes is proposed. The system is created based on a three-layer model which consists of Information flow layer, Document flow layer, and Presentation layer. This background of a supporting system which will be discussed in Chapter 3. A function of the supporting system is to streamline document flows in international trade transactions processes. This function is executed by three modules: (1) Generating information from document flows, (2) Reducing redundancy of the information flows, and (3) Generating document flows from information flows. This function of a supporting system which will be discussed in Chapter 4. Furthermore, experiments are conducted to investigate the performances of the proposed system in Chapter 5.

1.2 Purpose of thesis

The main purpose of this thesis is to propose a system for improving the efficiency of paperwork process in an international trade transaction by reducing redundancy and complexity of paperworks process. To achieve the main purposes, the study attempts to focus on the following objects.

(1) To investigate document flows and information flows among organizations of international trade transaction processes.

(2) To realize document flows and information flows of international trade transaction processes.

(3) To propose a method for improving efficiency of paperworks in international trade transaction processes.

(4) To realize the proposed method in the case of international trade

(5) To investigate the performances of the proposed method in the case of international trade transaction process

1.3 Research contributions

This thesis aims to propose a system for improving the efficiency of paperwork process in an international trade transaction. The research and theoretical contributions of this thesis can be summarized as follows.

Practical contribution A novel system for improving efficiency of paperworks in international trade transaction processes is proposed. Several situations of paperworks process in international trade transaction can be applied in the proposed system.

Theoretical contribution A diagrammatic and mathematical model for represent the system are proposed.

1.4 Structure of thesis

This thesis consists of six chapters in which shown in figure 1.1. This thesis is organized into three main parts in six chapters. The first part covers theoretical and methodological perspective through relevant literature (Chapter 1-2). The second part presents a model for improving efficiency of paperworks in international trade transaction processes (Chapter 3). The third part explains the proposed algorithms for reducing document flows based on the supporting system for improving efficiency of paperworks in international trade transaction processes (Chapter 4-5). Conclusions and future directions (Chapter 6) are presented at the final part of this thesis. Brief descriptions of the chapters are presented as followed.

Chapter 1: **Introduction**
Chapter 2: **Backgrounds**
Chapter 3: **A model of supporting system for improving efficiency of paperworks in international trade transaction processes**
Chapter 4: **Algorithms for reducing document flows based on the proposed model**
Chapter 5: **Experiments**
Chapter 6: **Conclusions and future directions**

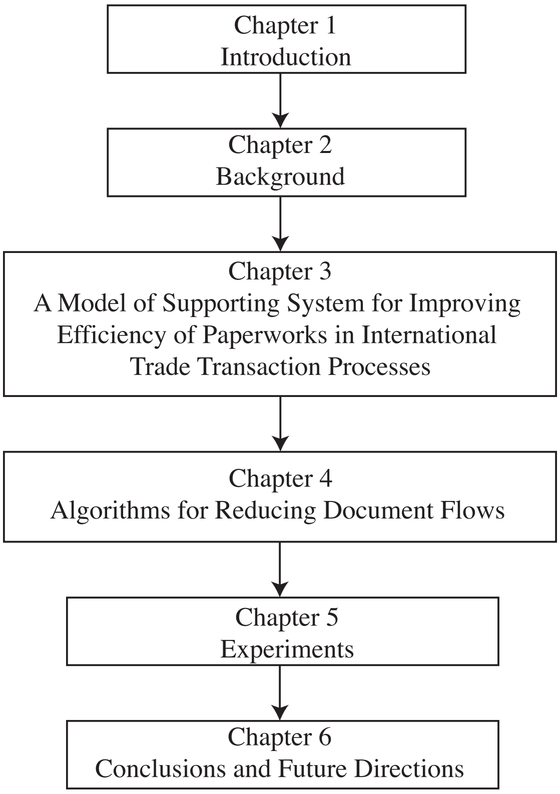


Figure 1.1 – Structure of the thesis.

2 Backgrounds

2.1 Introduction

The aim of this chapter is to present covers theoretical and methodological perspective through relevant literature. The following three topics are mentioned; the first one is the background of study, the second one is previous works, the last one is fundamental theory.

2.2 Background of study

2.2.1 International trade transaction

International trade is a concept of exchange of goods and services between people or entities in different countries. International trade processes between different countries have an important role in the economic development. In the period from 2008 - 2018, the volume of import and export has increased dramatically. In 2018, the volume of world trade, as measured by the average of exports and imports, grew by 3.0 percent, just above the 2.9 percent increase in world GDP over the same period [3] .

International trade create jobs and stimulates economic growth, as well as give domestic companies more experience in producing for foreign markets. The only way to stimulates international trade is to make trade process easier overall. Regional economic integration occurs to remove barriers of trading and customs unions between countries. For instance, the European Union (EU) is the regional economic integration in the Europe zone which aims to remove barriers to trade such as tariffs and border controls. In Southeast Asia, it also has the regional economic integration Association of Southeast Asian Nations (ASEAN). One of the aims of ASEAN is to accelerate economic growth, social progress, and cultural development. In the North America zone, the U.S., Canada, and Mexico, there is the NAFTA which aims to eliminate or reduce barriers to trade and investment. Although the aims of each regional economic integration are successful, limitations of international trade have remained. For example, each country has designed its own trade transaction processes without considering other countries' circumstances. International trade transaction process is not as easy as domestic trade transaction process. International markets are more dynamics, uncertain, and challenging because cultural diversities and political realities in several nations create plenty of barriers that need special attention.

Doing business [4] has considered several important dimensions of the regulatory environment as it applies to local firms. It provides quantitative indicators on regulation for starting a business, dealing with construction permits, getting electricity, registering property, getting credit, protecting minority investors, paying taxes, trading across borders, enforcing contracts and resolving insolvency. In the terms of trading across borders, they have reported that outdated and inefficient border procedures, inadequate infrastructure, and unreliable logistics services are reasons that cause the time and cost consuming. They collects the data included time and cost of international trade process, number of documents that needed to complete the transaction processes. In order to proceed in international trade processes, organizations have to follow procedure and handle various documents. Documents also contain various informations. Obviously, a paperwork process is important to trade facilitation for international trade. The paperwork process also can be represented as an ease of doing business between two countries. However, it is one of the bottlenecks in the international trade. It has been observed that border crossings still remain the weakest links in many economic corridors [5]. Weak points of these processes are redundant clearance process, and requirement of multiple documents in different formats, differences of laws, regulations and languages.

Moreover, international trade has evolved into a complex network of organizations, both inside and outside countries; government agencies under the ministry of trade, commerce, inspection agencies, customs and central excise, banking institutions, forwarding agents, shipping companies or airlines, carriers for inland transportation, etc [6]. The documents are supposed to cover the maximum amount of information to avoid a lack of information for each organization. Whereas there are many organizations who also need their own documents.

These facts lead to complexity in international trade networks. A key factor that contributes to the complexity of border crossing network is the same element of document occurring as a redundancy. The redundancy is perceived as a kind of noise that affects the quality of the network [7]. This leads us to design a system to deal with the redundancy and information diversity problems.

2.3 Previous works

Several studies have been conducted in supply chain management (SCM) in trade transactions [8–11]. These studies have been mainly focused on domestic trade transactions, so they have not been taken the transaction procedures among different countries and organizations into consideration.

Jolayemi has applied a linear programming model for production-distribution and transportation planning to enhance an organizations operational efficiency and financial performance [12]. In Yung and Yangs study, genetic algorithm has been applied to upstream and downstream firms to obtain combined solutions of supply chain to achieve efficient and effective order processing in the operation [13]. Wang and Liang proposed a multi-objective linear programming model to minimize production cost, shortage cost, and changes in the workforce level [14]. The main findings of these studies are focused on reducing the costs of transportation, production planning, and cost of inventory in the trade transactions.

Improving efficiency of paperworks in offices is an important problem for business and many studies have been conducted. For example, Dewan, et al. proposed a method to consolidate tasks in a business process [15]. The aim of the approach is to reduce losses and delays in inter-task communications by consolidating related tasks. They considered four parameters; (1) Precedence of information flows (2) Loss of specialization (3) Reduction in handoffs, and (4) Technology supports costs. Their method changed the information precedence and the overall process network topology through task consolidation. Their methodology is an extension of the conventional PERT/CPM approach. However, this proposal is most applicable to routine transactional processes such as order fulfillment or accounts payable in a business process. By using the consolidating related tasks as a unified methodology to come up with redesign initiatives is based on the common observation that delay and hand-off are one of the main reason why many process are inefficient.

Nonaka has also proposed a method for consolidating workflow processes [16]. In the study, an access permission to information of each organization in a business process is focused. Such as a case where the authorization to personnel information is different between the subsection chief and the section chief. Some participants may not be able to reference information necessary for decision making. In such a case, the participant also cannot change or enter necessary information. The aim of the study is to improve an office environment of a workflow processes and to simplify activities in a workflow system for participants. This invention provides a workflow engine connected with multiple computer terminals to manage workflows. In the method of the invention, there are several steps for consolidating workflow processes; (1) determining the range of consolidating multiple consecutive nodes to be processed by the participant based on a workflow definition stored in a storage device, (2) determining the highest level of access permission to each field with in the consolidation from the workflow definition, (3) acquiring work items selectable for each node within the determined consolidation range from the workflow definition stored in the storage device,(4) acquiring the layout definition of a form to be provided to the participant from the workflow definition, and

(5) generating a form as consolidated information based on the access permission and the layout definition.

In Fridgen, Gilbert, et al.[17], they have developed a prototype system based on blockchain technology to improve a cross-organization workflows by extending a workflow management system. One major advantage of a cross-organizational WfMS based on Blockchain is a cross-organizational workflow are enabled without the need for one particular authority. Their prototype provides an example how to design and implement a Blockchain solution in the field of BPM. Blockchain-based solution may face challenges public goods are usually prone to, such as overuse, unclear responsibilities, or different opinions of users. They conducted interviews for experts to confirm the effects of the prototype system. All interviewees emphasized that Blockchain technology can play an important role for the financial services industry if standardization and applicability is developed further. Their prototype does not address all aspects necessary for a productive system in full detail. Also, distinct risk, benefit, or cost considerations of Blockchain solutions do not yet exist.

Orantes Jimenez, S. D. et al. [18] has suggested the use of paperless office for Small and Medium Enterprises (SMEs) or large companies. By introducing paperless office, we can improve the efficiency of paperworks because we can get supports of information and communication technologies. The authors said there are three main advantages by using a paperless office; (1) money saving, (2) space saving, and (3) environmental care. However, before making any changes, companies need to have a strategy, for example, if they are to scan documents to employ digitally is necessary to determine permissions to restrict access to files and folders, also create naming conventions for documents and folders for recovery it efficient. The company will have to invest in and that will have huge costs and capital investment. Hardware that may need to be purchased includes scanners, servers and communication devices such as smartphones and tablets for those in the field to keep in touch. Software that may be needed consists typically of integration solutions that help different systems to communicate with other systems, document archiving and communication applications. Some of their older employees may not be as receptive (compared to the younger staff) to the broad use of technology that is required to go paperless. Moreover, the international standards for paperless trade have not been fully determined.

Civelek, et al. [1] investigated redundancy and complexity of paperworks in international trade transaction processes and suggested us to use electronic paperwork systems. This study observed on e-document in the field of foreign trade. It is expected that all document functions will be combined with a single application in an electronic environment in the future. All organizations involved in this process must come together on a common system so that a foreign trade transaction is carried out over the internet on a single document from the beginning to the end. However, this process does not seem like to take place in a very short time. The establishment of an online infrastructure that can bring together all the parties involved in international trade transactions need international cooperation by countries as well as major investments. It is observed that the establishment of such cooperation is difficult. As a result, they concluded that the processes can be executed through an online platform which all organizations involved in the process can access. They said that the number of documents can be decreased, and complexities of paperwork process can be reduced by introducing the electronic documents systems.

Ponanan, et.al. [19] have proposed a basic framework of supporting system for international trade transaction process for absorbing differences of formats and types of documents. The model is designed from three aspects, information flow, document flow and presentation. Then, an international logistics ontology is developed to describe the international trade transaction model. An algorithm for optimizing information flow is proposed for removing redundancies of information flows in the international trade transaction system. This framework is well designed, but the implementing way has not shown yet.

To conclude the several of researches on system for improving efficiency of paperworks in offices, strengths and weaknesses of literature review are summarized in Table 2.1.

Table 2.1 – Summary of strengths and weaknesses of previous works

Authors	Goal	Strengths	Weaknesses
Dewan et al. [15]	To reduce delays in inter-task communications by consolidating tasks	- Suitable for a business process - Extension of the conventional PERT/CPM	- Only concentrate on routine transactional processes - Can be time and cost consuming - Difficult to interpret
Nonaka [16]	To improve workflow in an office environment	- Suitable for a business process - Suitable for a large process - Highlight of a level of access permission of participants in a process - Suitable for instructing a workflow system as a computer	- Time and cost consuming - Difficult to construct - Difficult to use - Easily becomes complicated
Orantes et al. [18]	To improve quality and accessibility of services of an office	- Idea and concept are easy to apply - Flexible and easy to maintain - Space saving - Environment care - Supported by information technology and communication (ICT)	- Time and cost consuming - Only concentrate on internal organization in an office - Lack of standard of paperless trade - Do not include redundancy of information in documents

Table 2.1 – Summary of strengths and weaknesses of previous works

Authors	Goal	Strengths	Weaknesses
Civelek et al. [1]	To improve a document system in the field of foreign trade	- Highlight on document of a foreign trade transaction - Supported by e-document system - Present a useful of using e-documents	- Time and cost consuming in construction - Do not have standard of electronic documents - Difficult to integrate all parties involved in foreign trade transaction - Easy become complicate
Fridgen et al. [17]	To improve a cross-organizational workflow	- Highlight on developing a Blockchain prototype to improve a cross-organizational workflow - Suitable for a business processes - Supported by Blockchain technology	- Lack of standard of blockchain technology - Lack of aspect for a productive system in full details - Difficult to construct - Do not include distinct risk, benefit, or cost considerations of Blockchain solutions
Ponanan et.al. [19]	To improve an international trade transaction process by optimizing document flows	- Suitable for international trade transaction processes - Highlight on informations and documents - Can provide several language for the users - Reducing redundancy of information of document flows	- Only concentrate on international trade transaction processes among ASEAN countries - Lack of the implementing way

In these studies, business processes are represented by using graph structures and conceptual ideas of the methodologies are shown. However, most of the previous works have not considered about processing documents among different organizations or countries. As same as our motivation, their approaches aim to improve the efficiency of business. Basically, their approaches do not change the network structures, and change the tasks which are conducted on the networks. Most of the previous works have not considered about re-construct structures of network and re-design documents format. On the other hand, our approach aims to re-construct structures of network, and solve the problem more radically. The mechanism in this study consider to re-design document format and improve efficiency of paperworks processes.

2.4 Graph theory and Set theory

In this section, the definitions and concepts of graph and definitions of symbols based on set theory are shown.

2.4.1 Graph theory

Graph theoretical concepts are widely used to study and model various applications, in different areas [20].

In [21], A graph G is an ordered triple $(V(G), E(G), \phi_G)$ consisting of a set of $V(G)$ of nodes, a set $E(G)$ of edges which connect the nodes, and an incidence function ϕ_G that associates with each edge of G an unordered pair of vertices of G. If e is an edge and u and v are nodes such that $\phi_G(e) = (u, v)$, then e is said to join u and v; the nodes u and v are called the ends of e.

In real life, there are various graphical models applications such as manufacturing, finance, steel production, handwriting recognition, network flow, etc [22–24]. In these papers, business processes are represented by using graph structures and conceptual ideas of the methodologies are shown. Many mechanisms for optimizing database systems have been proposed. These studies also related the paper because a document can be considered as a record of database.

Bordoloi and Kalita [25] have proposed an approach for designing graph database models from existing relational databases. In this article, database structures are represented as graph structures. In the process of converting database structure to graph structure, intersection operation of set theory are used. Adji and Setiawan [26] have proposed an enhanced graph transforming algorithm to reduce the redundancy of results of transforming data from relational databases to NoSQL database. This study shows that modeling with graph and set theory is a promised way to reduce redundancy of a structure. In [27], they presented a graph technique for resolving a graph theory problem. They presented a high performance graph indexing mechanism to address the graph query problem on large networks. Wang, et al. [28] have provided a graph based document representation in which documents are represented as dependency graph. Nodes are identified as words and edges represent the relationship between pair of words. Rafi, et al. [29] also considered document as a document graph. Graph data structures can easily captures the non-linear relationships of nodes, the documents contains various feature terms that can be non-linearly connected hence a graph can easily represent this information.

Those papers have resolved a graph problem by the operations on the graph such as union and intersection of sets. In this study, paperwork processes can be represented by graph structure. Each node stands for organization. Each edge stands for path of information flow or path of document flow. Process of paperworks in an international trade transaction named X is described as:

$$\mathbb{P}_X = (\mathbb{G}_X, \mathbb{D}_X, \mathbb{I}_X, \mathbb{Q}_X, \mathbb{R}_X)$$

Structure of process X is described as:

$$\mathbb{G}_X = (\mathbb{V}_X, \mathbb{E}_X)$$

$\mathbb{V}_X$ stands for a set of nodes which represent organizations in process X, $\mathbb{E}_X$ stands for a set of edges which represent a path of document flows in process X, $\mathbb{D}_X$ stands for a set of documents used in process X, $\mathbb{I}_X$ stands for a set of all of informations used in process X, and $\mathbb{Q}_X$ stands for a set of all required informations of each organization in process X.

2.4.2 Definitions of symbols based on set theory

In order to realize the proposed system for reducing the redundancy of paperworks processes, set theory is applied. A set is a collection of existing objects. The objects can be considered as a member of a set. It can be numbers, people, letters of the alphabet, other sets, and so on.

In this study, symbols based on set theory are used for representing elements of paperworks processes. A process of paperworks in an international trade transaction named X is described as:

$$\mathbb{P}_X = (\mathbb{G}_X, \mathbb{D}_X, \mathbb{I}_X, \mathbb{Q}_X, \mathbb{R}_X)$$

A structure of process X is described as:

$$\mathbb{G}_X = (\mathbb{V}_X, \mathbb{E}_X)$$

here, $\mathbb{V}_X$ stands for a set of nodes which represent organizations in process X, and $\mathbb{E}_X$ stands for a set of edges which represent a path of document flows in process X. An edge from node v_i to node v_j is represented as $(\mathrm{v}_i, \mathrm{v}_j)(\in \mathbb{E}_X)$.

A document D_a $(\in \mathbb{D}_X)$ is represented as a set of informations included in the document:

$$\mathrm{D}_a = \{\mathrm{i}_1, \mathrm{i}_2, \cdots \mathrm{i}_n\}$$

here, $\mathrm{i}_m(\in \mathrm{D}_a)$ stands for an information m included in Document a. A set of all of informations used in process X is represented as $\mathbb{I}_X$. Obviously, $\forall \mathrm{D} \subset \mathbb{I}_X$. $\mathbb{Q}_X$ stands for a set of all required informations of each organization in process X.

$\mathbb{R}_X$ stands for a set of route of documents. Route of document a is represented as $\mathrm{R}^{\mathrm{d}}_a(\in \mathbb{R}_X)$. Route of information m is represented as $\mathrm{R}^{\mathrm{i}}_m$.

Moreover, operations of set theory are applied in the mechanism for reducing the redundancy of paperworks processes. Union is used for combing edges of routes of documents. Intersection is used for finding the same edges of routes of document.

2.5 Conclusion

In this chapter, the three topics that concerned in this study have been mentioned such as the background of study, previous works, and fundamental theory; graph theory and set theory. The basic concept and application of each topic have been shown. The notation of graph theory and set theory are the background theories and manipulate the main objective of this paper. In the chapter 3-4, graph theory and set theory are employed for describing international trade transaction processes.

3 A model of supporting system for improving efficiency of paperworks in international trade transaction processes

3.1 Introduction

The aims of this chapter are (1) to investigate document flows and information flows among organizations of international trade transaction processes and (2) to realize document flows and information flows of international trade transaction processes. In this chapter, graph theory and set theory are employed for describing international trade transaction processes. For this chapter, an international trade transaction process model consists of three layers: (1) Information flow layer, (2) Document flow layer, and (3) Presentation layer. It is necessary to have a common structure to describe information in documents that used in a transaction process. In this study, a mathematical model for representing international trade transaction processes is defined.

3.2 A mathematical model of supporting system for improving efficiency of paperworks in international trade transaction processes

A framework of supporting system for international trade transaction processes was proposed [19]. The framework is created based on a three-layer model which consists of Information flow layer, Document flow layer, and Presentation layer. On Document flow layer, flows of documents used in the process are represented; on Information flow layer, information flows are described; on Presentation layer, labels of informations are defined in several languages which required in the process.

Details of each layer are shown below:

Document flow layer : Flow of all documents in a process are represented by a network model on this layer.

Information flow layer : Flow of all informations in a process are represented on this layer.

Presentation layer : Labels of informations are described in several languages. Documents are translated into suitable languages for users on this layer.

Figure 3.1 illustrates the three-layer model.

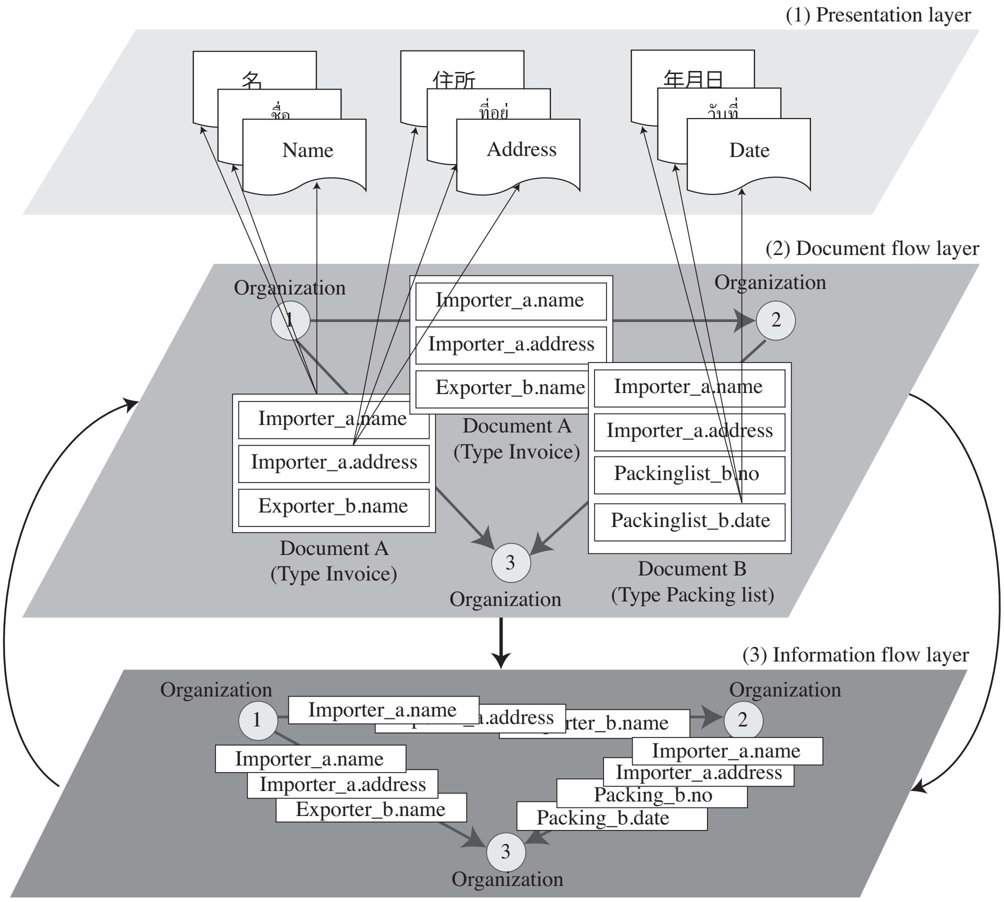


Figure 3.1 – A framework of support system for international trade transaction.

In order to implement the framework, notation of document flows and information flows are needed. It is necessary to have a common structure to describe information in documents used in a transaction process. A mathematical model for representing international trade transaction processes is defined. By using this model, document flows and information flows can be represented as a mathematical model for communicating between each layer in the supporting system as mentioned before.

A process of paperworks in an international trade transaction named X is described as:

$$\mathbb{P}_X = (\mathbb{G}_X, \mathbb{D}_X, \mathbb{I}_X, \mathbb{Q}_X, \mathbb{R}_X)$$

A structure of process X is described as:

$$\mathbb{G}_X = (\mathbb{V}_X, \mathbb{E}_X)$$

here, $\mathbb{V}_X$ stands for a set of nodes which represent organizations in process X, and $\mathbb{E}_X$ stands for a set of edges which represent a path of document flows in process X.

$\mathbb{D}_X$ stands for a set of documents used in process X. A document D_a ($\in \mathbb{D}_X$) is represented as a set of informations included in the document:

$$\mathrm{D}_a = \{\mathrm{i}_1, \mathrm{i}_2, \cdots \mathrm{i}_n\}$$

here, $\mathrm{i}_m(\in \mathrm{D}_a)$ stands for an information m included in Document a. A set of all of informations used in process X is represented as $\mathbb{I}_X$. Obviously, $\forall \mathrm{D} \subset \mathbb{I}_X$. $\mathbb{Q}_X(\subset \mathbb{I}_X)$ stands for a set of all required informations in a process X. A set of required informations of organization r is represented as q_r ($\in \mathbb{Q}_X$).

An edge from node i to node j is represented as $(\mathrm{v}_i, \mathrm{v}_j)(\in \mathbb{E}_X)$. $\mathbb{R}_X$ stands for a set of route of documents. Route of document a is represented as $\mathrm{R}^{\mathrm{d}}_a(\in \mathbb{R}_X)$. Route of information m is represented as $\mathrm{R}^{\mathrm{i}}_m$.

3.3 An example of international trade transaction process

An example of international trade transaction process X is shown to illustrate the proposed mathematical model. In the example, three types of documents; (1) Document type a (2) Document type b , and (3) Document type c are used. In each document, several informations are described as shown in table 3.1.

Table 3.1 – Document used in the example

Type of document	Notation	Informations	Notation
Document type a	D_a	Information 1	i_1
		Information 2	i_2
		Information 3	i_3
Document type b	D_b	Information 1	i_1
		Information 2	i_2
Document type c	D_c	Information 1	i_1
		Information 3	i_3

In this process, there are five organizations; (1) Organization 1, (2) Organization 2, (3) Organization 3, (4) Organization 4, and (5) Organization 5. Table 3.2 shows notation representing organizations in the example.

Table 3.2 – Notation of organizations in the example

Organization	Notation
Organization 1	v_1
Organization 2	v_2
Organization 3	v_3
Organization 4	v_4
Organization 5	v_5

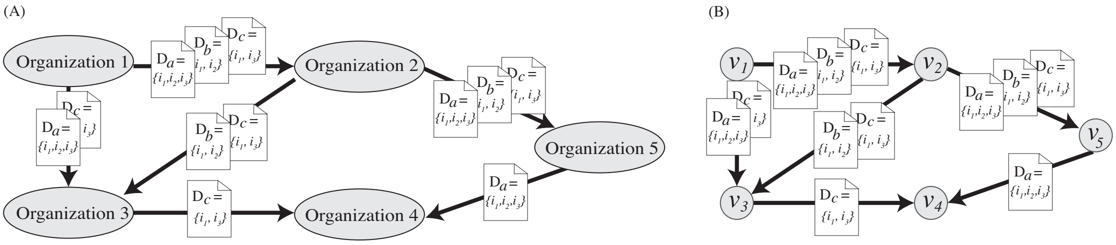


Figure 3.2 – An example of document flows.

In Fig. 3.2 (A), the document flow of the example are shown. Each node stands for organization and each arrow stands for a path of document flow. In Fig. 3.2 (B), the document flows are represented as a graph structure by using the symbols in Table 3.1 and 3.2. The process in Fig. 3.2 can be described as formulae in Table 3.3 by using the proposed mathematical model.

3.4 Conclusion

In this chapter, an international trade transaction process model is introduced. A mathematical model for representing information flows and document flows in international trade transaction processes is proposed. An example of paperworks process is shown to illustrate the usage of the proposed mathematical model. As a result of the example, we can see that international trade transaction processes are shown as networks. Each node stands for an organization, and each edge stands for a flow of an information. Information flows and documents flows of paperworks in international trade transaction processes can be realized as an actual system by using the proposed model.

Table 3.3 – A Mathematical model of the example

$\mathbb{P}_X = (\mathbb{G}_X, \mathbb{D}_X, \mathbb{I}_X, \mathbb{Q}_X, \mathbb{R}_X)$
$\mathbb{G}_X = (\mathbb{V}_X, \mathbb{E}_X)$
$\mathbb{V}_X = \{\mathrm{v}_1, \mathrm{v}_2, \mathrm{v}_3, \mathrm{v}_4, \mathrm{v}_5\}$
$\mathbb{E}_X = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_1, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5), (\mathrm{v}_3, \mathrm{v}_4), (\mathrm{v}_5, \mathrm{v}_4)\}$
$\mathbb{D}_X = \{\mathrm{D}_a, \mathrm{D}_b, \mathrm{D}_c\}$
$\mathrm{D}_a = \{\mathrm{i}_1, \mathrm{i}_2, \mathrm{i}_3\}$
$\mathrm{D}_b = \{\mathrm{i}_1, \mathrm{i}_2\}$
$\mathrm{D}_c = \{\mathrm{i}_1, \mathrm{i}_3\}$
$\mathbb{I}_X = \{\mathrm{i}_1, \mathrm{i}_2, \mathrm{i}_3\}$
$\mathbb{Q}_X = \{\mathrm{q}_1, \mathrm{q}_2, \mathrm{q}_3, \mathrm{q}_4, \mathrm{q}_5\}$
$\mathbb{R}_X = \{\mathrm{R}^{\mathrm{d}}_a, \mathrm{R}^{\mathrm{d}}_b, \mathrm{R}^{\mathrm{d}}_c\}$
$\mathrm{R}^{\mathrm{d}}_a = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_1, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5), (\mathrm{v}_5, \mathrm{v}_4)\}$
$\mathrm{R}^{\mathrm{d}}_b = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_2, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5)\}$
$\mathrm{R}^{\mathrm{d}}_c = \{(\mathrm{v}_1, \mathrm{v}_2), (\mathrm{v}_1, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_3), (\mathrm{v}_2, \mathrm{v}_5), (\mathrm{v}_3, \mathrm{v}_4)\}$

4 Algorithms for reducing document flows

4.1 Introduction

In this chapter, a fundamental of set theory as mentioned in chapter 2 is used. The aim of this chapter is to propose a method for improving efficiency of paperworks in international trade transaction processes.

In this study, a supporting system for improving efficiency of paperworks in international trade transaction processes is proposed. The aim of the supporting system is to reduce redundancy of document flows in international trade transaction processes. The supporting system has three main steps: (1) converting document flows to information flows, (2) reducing information flows, and (3) generating document flows from information flows.

Details of each step are shown below.

(1) **Converting document flows to information flows**
Current document flows on document flow layer are converted to information flows. A document can be considered as a set of informations because several informations are described in it. Obviously, informations contained in a document have the same route with the document. Thus, by extracting informations, document flows can be converted into information flows.

(2) **Reducing information flows**
In this step, information flows on Information flow layer are focused. On this layer, repeated information flows are eliminated by using a proposed algorithm for reducing information flows.

(3) **Generating document flows from information flows**
Sets of informations are created by gathering informations which have the same

routes. Then, new documents are generated as each set of information corresponds to each document. Flow of each new document is generated from reducing information flows.

Figure 4.1 shows a basic idea of reducing an international trade transaction process.

4.2 Algorithms for reducing document flows

(1) Converting document flows to information flows

As mentioned above, each document can be considered as a set of informations. Obviously, all informations contained in a document have the same route with the document. In addition, same type of informations are used in several documents. So, $\mathrm{R}^{\mathrm{i}}_m$, a route of information m, can be deduced as shown in Equation (4.1).

$$\mathrm{R}^{\mathrm{i}}_m = \{ \bigcup_{\mathrm{D}_a \in \mathbb{D}_X} \mathbb{R}^{\mathrm{d}}_a | \; \mathrm{D}_a \cap \{\mathrm{i}_m\} \neq \phi \} \tag{4.1}$$

(2) Reducing information flows

Information flows are reduced by using algorithm 1 for reducing routes of information:

Algorithm 1 Reducing routes of information m

Input $\mathbb{I}_X$: A set of all information in a process X
Output $\mathbb{I}_X$: A set of all information in a process X
while $\exists \mathrm{v}_n \in \mathbb{V}_X, \deg^+(\mathrm{v}_n) > 1$ **do**
Find v_c, where $\deg^+(\mathrm{v}_c) = \max(\deg^+(\mathrm{v}_n)), \forall \mathrm{v}_n \in \mathbb{V}_X$
Find v_r, where $\deg^-(\mathrm{v}_r) = \max(\deg^-(\mathrm{v}_n)), \forall (\mathrm{v}_r, \mathrm{v}_c) \in \Phi(\mathbb{E}_X)$
    while $\deg^+(\mathrm{v}_c) > 1$ **do**
        $\mathrm{R}^{\mathrm{i}}_m \leftarrow (\mathrm{R}^{\mathrm{i}}_m - (\mathrm{v}_r, \mathrm{v}_c))$
        Find v_c, where $\deg^+(\mathrm{v}_c) = \max(\deg^+(\mathrm{v}_n)), \forall \mathrm{v}_n \in \mathbb{V}_X$
        Find v_r, where $\deg^-(\mathrm{v}_r) = \max(\deg^-(\mathrm{v}_n)), \forall (\mathrm{v}_r, \mathrm{v}_c) \in \Phi(\mathbb{E}_X)$
    end while
end while

Here, $\deg^+(\mathrm{v})$ stands for the number of indegree of node v, $\deg^-(\mathrm{v})$ stands for the number of outdegree of node v. ϕ stands for a mapping from an edge to a pair of nodes. For example, $\phi(e) = (\mathrm{v}_1, \mathrm{v}_2)$ stands for a situation where edge e connects node v_1 and v_2.

(3) Generating document flows from information flows

Documents which include only one information are created. Here, the number of documents become same as the number of informations in the process. Each document has the same route with information which included in the document. Then, a pair of documents are found. If they have a common path of their route of document, these

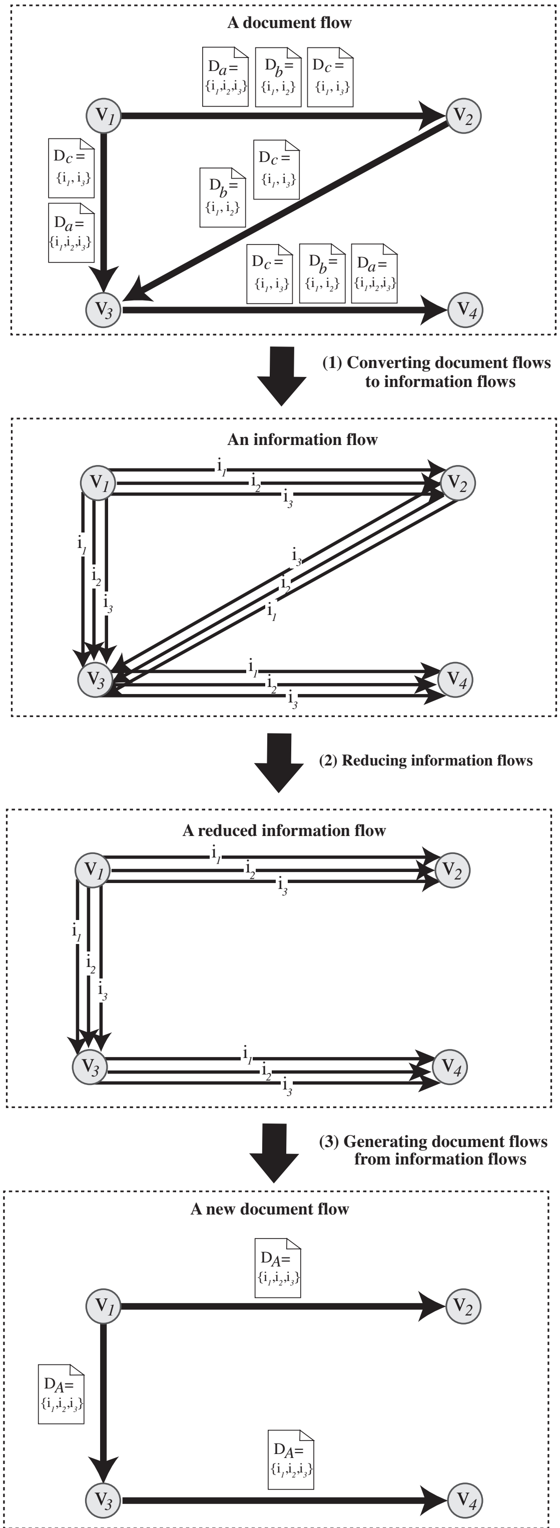


Figure 4.1 – A basic idea of reducing an international trade transaction process.

documents can be merged. Algorithm 2 shows the algorithm to generate document flows from information flows.

Algorithm 2 Generating routes of document from routes of information

1: Input $\mathbb{I}_X$: A set of all information in a process X
2: Output $\mathbb{D}^*_X$: Generated Document flows
3: Create a set of document $\mathbb{D}_X = \{\mathrm{D}_1, \mathrm{D}_2, ..., \mathrm{D}_{|\mathbb{I}_X|}\}, |\mathbb{D}_X| = |\mathbb{I}_X|, \mathbb{R}_X = \phi$
4: $F_{max} = 0$
5: **for** $j = 0; j < |\mathbb{D}_X| - 1; j++$ **do**
6: create $\mathrm{R}^{\mathrm{d}}_j$, $\mathrm{R}^{\mathrm{d}}_j \leftarrow \mathrm{R}^{\mathrm{i}}_j$, $\mathbb{R}_X \leftarrow \mathbb{R}_X \cup \{\mathrm{R}^{\mathrm{d}}_j\}$
7: **end for**
8:
9: **for** $a = 0; a < |\mathbb{D}_X| - 1; a++$ **do**
10: **for** $b = a + 1; b < |\mathbb{D}_X|; b++$ **do**
11: **if** $\mathrm{R}^{\mathrm{d}}_a \cap \mathrm{R}^{\mathrm{d}}_b = \phi$ **then**
12: **continue**
13: **else**
14: **if** $\mathrm{R}^{\mathrm{d}}_a = \mathrm{R}^{\mathrm{d}}_b (\neq \phi)$ **then** ▷ Route **a** and route **b** are same.
15: create $\mathrm{D}_c \leftarrow \mathrm{D}_a \cup \mathrm{D}_b, \mathrm{R}^{\mathrm{d}}_c \leftarrow \mathrm{R}^{\mathrm{d}}_a$
16: $\mathbb{D}_X \leftarrow \mathbb{D}_X \cup \{\mathrm{D}_c\}, \mathbb{R}_X \leftarrow \mathbb{R}_X \cup \{\mathrm{R}^{\mathrm{d}}_c\}$
17: $\mathbb{D}_X \leftarrow \mathbb{D}_X - \{\mathrm{D}_a, \mathrm{D}_b\}, \mathbb{R}_X \leftarrow \mathbb{R}_X - \{\mathrm{R}^{\mathrm{d}}_a, \mathrm{R}^{\mathrm{d}}_b\}$
18: $F_{\mathbb{D}_X} = \alpha(f_1) + \beta(f_2)$ ▷ Calculate evaluation function
19: **else**
20: **if** $\mathrm{R}^{\mathrm{d}}_a \cap \mathrm{R}^{\mathrm{d}}_b \neq \phi$ **then** ▷ Route **a** and route **b** have same routes.
21: create $\mathrm{D}_c \leftarrow \mathrm{D}_a \cup \mathrm{D}_b$, $\mathrm{R}^{\mathrm{d}}_c \leftarrow \mathrm{R}^{\mathrm{d}}_a \cap \mathrm{R}^{\mathrm{d}}_b$
22: $\mathrm{R}^{\mathrm{d}}_a \leftarrow \mathrm{R}^{\mathrm{d}}_a - \mathrm{R}^{\mathrm{d}}_c, \mathrm{R}^{\mathrm{d}}_b \leftarrow \mathrm{R}^{\mathrm{d}}_b - \mathrm{R}^{\mathrm{d}}_c$
23: $\mathbb{D}_X \leftarrow \mathbb{D}_X \cup \{\mathrm{D}_c\}, \mathbb{R}_X \leftarrow \mathbb{R}_X \cup \{\mathrm{R}^{\mathrm{d}}_c\}$
24: $F_{\mathbb{D}_X} = \alpha(f_1) + \beta(f_2)$ ▷ Calculate evaluation function
25: **else**
26: **if** $\mathrm{R}^{\mathrm{d}}_a \subset \mathrm{R}^{\mathrm{d}}_b$ **then** ▷ Route **b** incluldes route **a**.
27: create $\mathrm{D}_c \leftarrow \mathrm{D}_a \cup \mathrm{D}_b$, $\mathrm{R}^{\mathrm{d}}_c \leftarrow \mathrm{R}^{\mathrm{d}}_b$
28: $\mathbb{D}_X \leftarrow \mathbb{D}_X \cup \{\mathrm{D}_c\}, \mathbb{R}_X \leftarrow \mathbb{R}_X \cup \{\mathrm{R}^{\mathrm{d}}_c\}$
29: $\mathbb{D}_X \leftarrow \mathbb{D}_X - \{\mathrm{D}_b\}, \mathbb{R}_X \leftarrow \mathbb{R}_X - \{\mathrm{R}^{\mathrm{d}}_b\}$
30: $F_{\mathbb{D}_X} = \alpha(f_1) + \beta(f_2)$ ▷ Calculate evaluation function
31: **end if**
32: **end if**
33: **end if**
34: **end if**
35: **Goto** line 9
36: **end for**
37: **if** $F_{\mathbb{D}_X} > F_{max}$ **then** ▷ Choose a candidate which has the maximum evaluation function
38: $F_{max} \leftarrow F_{\mathbb{D}_X}$
39: $\mathbb{D}^*_X \leftarrow \mathbb{D}_X$ ▷ $\mathbb{D}_X$ has been changed.
40: **end if**
41: **end for**

First, documents which include only one information are created (line 3). Eventually, the number of documents become same as the number of informations in the process. Then, routes of documents are created. Each route is the same as route of information included in the document (line 5 - 7). Each document is checked if it is possible to merge with other documents and evaluation function is calculated (line 9 - 40). If a document is merged with other documents, the checking process starts from first again (line 35). Finally, the maximum evaluation function is found and new document flows is generated (line 37 - 40).

4.3 Conclusion

In this chapter, a mathematical model for representing paperworks process have been presented. By using the proposed mathematical model, the algorithms used for reducing redundancy document flows in international trade transaction processes can implement. In this chapter, the major contribution is the diagrammatic and mathematical model for represent the system are proposed. In the next chapter, experiments are conducted for investigating the abilities of the proposed system.

5 Experiments

5.1 Introduction

In this chapter, two experiments are conducted for investigating the abilities of the proposed system in chapter 4. Two points of view are considered; (1) reducing redundancy of paperworks and (2) flexibility of the proposed system.

The first experiment is conducted for confirmimg the reducing redundancy of paperworks by using the proposed system. In this experiment, two examples are shown to illustrate the proposed system. The first example, the example A, is an export process from Thailand to Malaysia. The second example, the example B, is an export process from Lao PDR to Thailand. In the examples, the total number of documents and the total number of information transmissions are compared between original process and reduced process.

Besides, the second experiment is conducted for confirming the flexibility of the proposed system. When reducing document flows, the requirements of system designers must be considered. For example, someone could want to reduce the number of documents in a process, and the other one could want to reduce the number of informations included in a document. The proposed system can have several evaluation functions in accordance with the requirements of the system designers. In order to show the flexibility of the proposed system, a result of experiment was shown. The evaluation functions in the experiment, two types of the redundancy of paperwork processes are used as criteria; (1) redundancy of sharing information and (2) redundancy of using documents. By using the functions, they have a trade-off relationship. Two different situations of reducing redundancy in paperworks process are investigated; (1) designer place emphasis on reducing informations in a document and (2) designer place emphasis on reducing number of documents in a process.

5.2 Experiment 1

In this section, two examples of international trade transaction processes in ASEAN are shown to illustrate the details of the proposed algorithms. The first example, the example A, is an export process from Thailand to Malaysia. The second example, the example B, is an export process from Lao PDR to Thailand. Table 5.1 shows informations contained in each type of document which used in the examples.

Table 5.1 – Documents and informations used in examples

Type of document	Notation	Informations	Notation
Invoice	D_1	Invoice number	i_1
		Invoice date	i_2
		Importer name	i_3
		Importer address	i_4
		Exporter name	i_5
		Exporter address	i_6
Invoice	D'_1	Invoice number	i_1
		Invoice date	i_2
		Importer name	i_3
		Importer address	i_4
		Exporter name	i_5
		Exporter address	i_6
		Tax ID number	i_7
Bill of lading	D_2	Importer name	i_3
		Importer address	i_4
		Exporter name	i_5
		Exporter address	i_6
		Name of import vehicle	i_8
Bill of lading	D'_2	Importer name	i_3
		Importer address	i_4
		Exporter name	i_5
		Exporter address	i_6
		Name of import vehicle	i_8
Packing list	D_3	Packing list number	i_9
		Packing date	i_{10}
		Company of packing name	i_{11}
		Company of packing address	i_{12}
		Country of origin	i_{13}
		Number of packages	i_{14}
Packing list	D'_3	Name of import vehicle	i_8

Table 5.1 – Documents and informations used in examples

Type of document	Notation	Informations	Notation
		Packing list number	i_9
		Packing date	i_{10}
		Company of packing name	i_{11}
		Company of packing address	i_{12}
		Country of origin	i_{13}
		Number of packages	i_{14}
Export license	D_4	Importer name	i_3
		Importer address	i_4
		Exporter name	i_5
		Exporter address	i_6
		Country of origin	i_{13}
		Country of destination	i_{15}
Import permit	D_5	Importer name	i_3
		Importer address	i_4
		Exporter name	i_5
		Exporter address	i_6
		Number of permit	i_{16}
		Name of authorized agent	i_{17}
		Address of authorized agent	i_{18}
Certificate of origin	D_6	Importer name	i_3
		Importer address	i_4
		Exporter name	i_5
		Exporter address	i_6
		Country of destination	i_{15}
		Departure date	i_{19}
Cargo clearance	D_7	Importer name	i_3
		Importer address	i_4
		Exporter name	i_5
		Exporter address	i_6
		Country of origin	i_{13}
		Country of destination	i_{15}
Custom declaration	D_8	Importer name	i_3
		Importer address	i_4
		Exporter name	i_5
		Exporter address	i_6
		Country of origin	i_{13}

Table 5.1 – Documents and informations used in examples

Type of document	Notation	Informations	Notation
		Country of destination	i_{15}
Request for delivery	D_9	Importer name	i_3
		Importer address	i_4
		Exporter name	i_5
		Exporter address	i_6
		Number of packages	i_{14}
Container movement order	D_{10}	Importer name	i_3
		Importer address	i_4
		Exporter name	i_5
		Exporter address	i_6
Personal passport	D_{11}	Passport number	i_{20}
		Name of passport holder	i_{21}
		Sex	i_{22}
		Birthdate	i_{23}
Personal passport	D'_{11}	Passport number	i_{20}
		Name of passport holder	i_{21}
		Sex	i_{22}
		Birthdate	i_{23}
International transport permit	D_{12}	Number of packages	i_{14}
		ID of driver	i_{24}
		Name of driver	i_{25}
		Driver license number	i_{26}
International transport permit	D'_{12}	Number of packages	i_{14}
		ID of driver	i_{24}
		Name of driver	i_{25}
		Driver license number	i_{26}

Details of the examples are described below.

5.2.1 Example A: An export process from Thailand to Malaysia

Eight organizations; (1) Exporter, (2) Thailand's custom, (3) Importer, (4) Forwarding Agent, (5) Malaysia's immigration, (6) Shipping Agent, (7) Malaysia's custom, and (8) Port are related to the process. Twelve types of documents; including (1) invoice, (2) bill of lading, (3) packing list, (4) export license, (5) import permit, (6) certificate of origin, (7) cargo clearance, (8) custom declaration form, (9) request for delivery, (10) container movement order, (11) personal passport, and (12) international transport permit are used.

Table 5.2 – Notation of organizations in example A

Organization	Notation	Organization	Notation
Exporter	v_1	Malaysia's immigration	v_5
Thailand's custom	v_2	Shipping agent	v_6
Importer	v_3	Malaysia's custom	v_7
Forwarding agent	v_4	Port	v_8

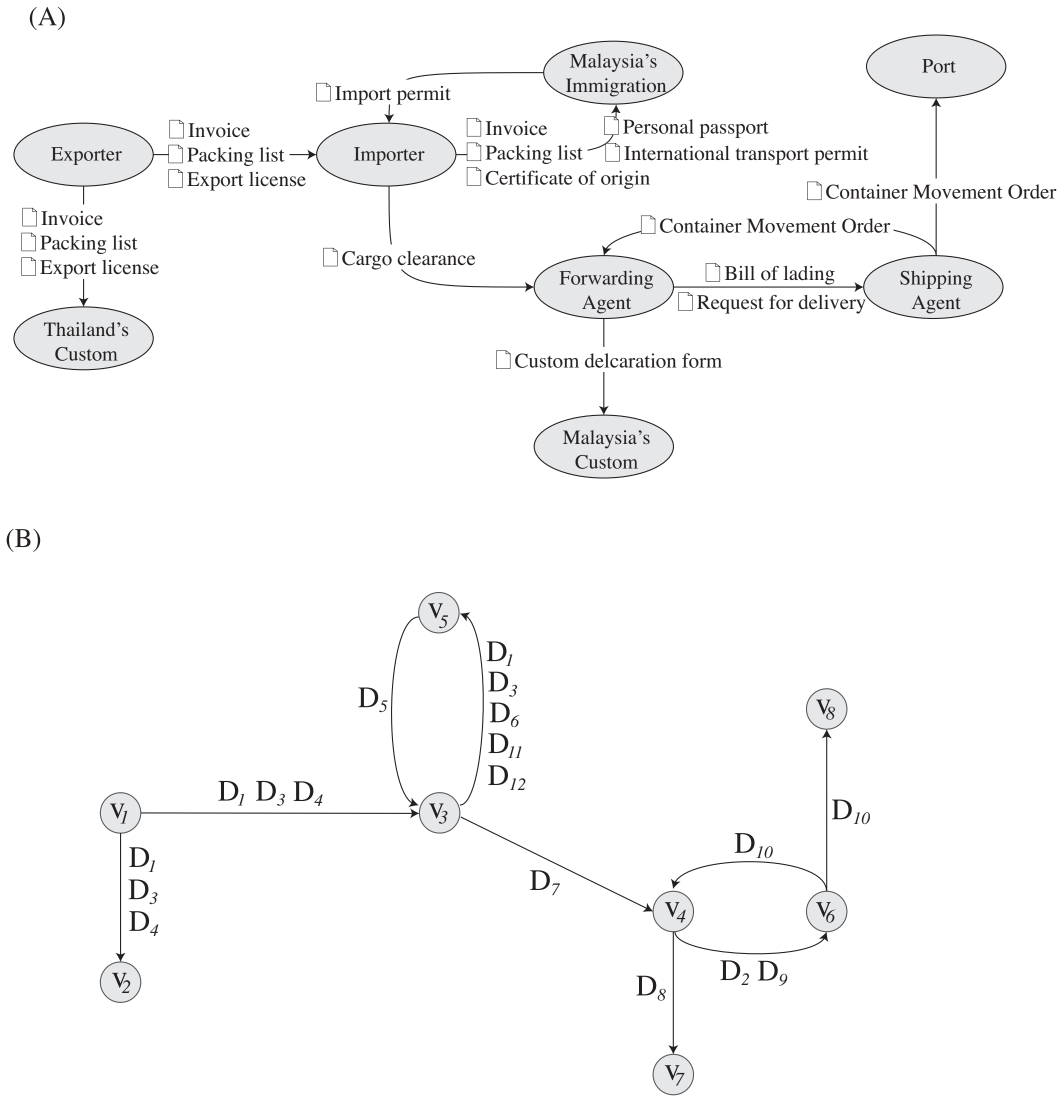


Figure 5.1 – Document flows of example A.

In Fig. 5.1 (A), the document flow of the example A are shown. Each node stands for an organization and each arrow stands for a path of document flow. In Fig. 5.1 (B), the document flows are represented as a graph structure by using the symbols in Table 5.1

and 5.2.

The process in Fig. 5.1 can be described as formulae in Table 5.3 by using the proposed mathematical model shown in chapter 3.

Table 5.3 – A Mathematical model of example A

$$
\begin{aligned}
&\mathbb{P}_A = (\mathbb{G}_A, \mathbb{D}_A, \mathbb{I}_A, \mathbb{Q}_A, \mathbb{R}_A)\\
&\mathbb{G}_A = (\mathbb{V}_A, \mathbb{E}_A)\\
&\mathbb{V}_A = \{v_1, v_2, v_3, v_4, v_5, v_6, v_7, v_8\}\\
&\mathbb{E}_A = \{(v_1, v_2), (v_1, v_3), (v_3, v_4), (v_3, v_5), (v_4, v_6), (v_4, v_7), (v_5, v_3), (v_6, v_4), (v_6, v_8)\}\\
&\mathbb{D}_A = \{D_1, D_2, D_3, D_4, D_5, D_6, D_7, D_8, D_9, D_{10}, D_{11}, D_{12}\}\\
&D_1 = \{i_1, i_2, i_3, i_4, i_5, i_6\}\\
&D_2 = \{i_3, i_4, i_5, i_6, i_8\}\\
&D_3 = \{i_9, i_{10}, i_{11}, i_{12}, i_{13}, i_{14}\}\\
&D_4 = \{i_3, i_4, i_5, i_6, i_{13}, i_{15}\}\\
&D_5 = \{i_3, i_4, i_5, i_6, i_{16}, i_{17}, i_{18}\}\\
&D_6 = \{i_3, i_4, i_5, i_6, i_{15}, i_{19}\}\\
&D_7 = \{i_3, i_4, i_5, i_6, i_{13}, i_{15}\}\\
&D_8 = \{i_3, i_4, i_5, i_6, i_{13}, i_{15}\}\\
&D_9 = \{i_3, i_4, i_5, i_6, i_{14}\}\\
&D_{10} = \{i_3, i_4, i_5, i_6\}\\
&D_{11} = \{i_{20}, i_{21}, i_{22}, i_{23}\}\\
&D_{12} = \{i_{14}, i_{24}, i_{25}, i_{26}\}\\
&\mathbb{I}_A = \{i_1, i_2, i_3, i_4, i_5, i_6, i_8, i_9, i_{10}, i_{11}, i_{12}, i_{13}, i_{14}, i_{15}, i_{16}, i_{17}, i_{18}, i_{19}, i_{20}, i_{21}, i_{22}, i_{23},\\
&\qquad i_{24}, i_{25}, i_{26}\}\\
&\mathbb{Q}_A = \{q_{v_1}, q_{v_2}, q_{v_3}, q_{v_4}, q_{v_5}, q_{v_6}, q_{v_7}, q_{v_8}, q_{v_9}, q_{v_{10}}\}\\
&\mathbb{R}_A = \{R^d_1, R^d_2, R^d_3, R^d_4, R^d_5, R^d_6, R^d_7, R^d_8, R^d_9, R^d_{10}, R^d_{11}, R^d_{12}\}\\
&R^d_1 = \{(v_1, v_2), (v_1, v_3), (v_3, v_5)\}, R^d_2 = \{(v_4, v_6)\},\\
&R^d_3 = \{(v_1, v_2), (v_1, v_3), (v_3, v_5)\}, R^d_4 = \{(v_1, v_2), (v_1, v_3)\},\\
&R^d_5 = \{(v_5, v_3)\}, R^d_6 = \{(v_3, v_5)\}, R^d_7 = \{(v_3, v_4)\},\\
&R^d_8 = \{(v_4, v_7)\}, R^d_9 = \{(v_4, v_6)\}, R^d_{10} = \{(v_6, v_4), (v_6, v_8)\},\\
&R^d_{11} = \{(v_3, v_5)\}, R^d_{12} = \{(v_3, v_5)\}
\end{aligned}
$$

(1) Converting document flows to information flows
In this step, routes of informations are generated from routes of documents shown in Fig. 5.1 by using the equation (4.1) on page 22. The generated routes of information are shown in Table 5.4.

(2) Reducing information flows
The generated information flows are reduced by using algorithm 1. For example, R^i_6 (Fig. 5.2) is reduced as followings:

line 1: $\deg^+(v_3) = 2 (> 0)$ and $\deg^+(v_4) = 2 (> 0)$, so loop is continued.

Table 5.4 – Routes of information of example A

$R^i_1 = \{(v_1,v_2),(v_1,v_3),(v_3,v_5)\}$	$R^i_{14} = \{(v_3,v_5)\}$
$R^i_2 = \{(v_1,v_2),(v_1,v_3),(v_3,v_5)\}$	$R^i_{15} = \{(v_1,v_2),(v_1,v_3),(v_3,v_4),(v_3,v_5),(v_4,v_7)\}$
$R^i_3 = \{(v_1,v_2),(v_1,v_3),(v_3,v_4),(v_3,v_5),(v_4,v_6),(v_4,v_7),(v_5,v_3),(v_6,v_4),(v_6,v_8)\}$	$R^i_{16} = \{(v_5,v_3)\}$
$R^i_4 = \{(v_1,v_2),(v_1,v_3),(v_3,v_4),(v_3,v_5),(v_4,v_6),(v_5,v_3),(v_6,v_4),(v_6,v_8)\}$	$R^i_{17} = \{(v_5,v_3)\}$
$R^i_5 = \{(v_1,v_2),(v_1,v_3),(v_3,v_4),(v_3,v_5),(v_4,v_6),(v_4,v_7),(v_5,v_3),(v_6,v_4),(v_6,v_8)\}$	$R^i_{18} = \{(v_5,v_3)\}$
$R^i_6 = \{(v_1,v_2),(v_1,v_3),(v_3,v_4),(v_3,v_5),(v_4,v_6),(v_5,v_3),(v_6,v_4),(v_6,v_8)\}$	$R^i_{19} = \{(v_5,v_3)\}$
$R^i_8 = \{(v_1,v_2),(v_1,v_3),(v_3,v_5),(v_4,v_6)\}$	$R^i_{20} = \{(v_3,v_5)\}$
$R^i_9 = \{(v_1,v_2),(v_1,v_3),(v_3,v_5)\}$	$R^i_{21} = \{(v_3,v_5)\}$
$R^i_{10} = \{(v_1,v_2),(v_1,v_3),(v_3,v_5)\}$	$R^i_{22} = \{(v_3,v_5)\}$
$R^i_{11} = \{(v_1,v_2),(v_1,v_3),(v_3,v_5)\}$	$R^i_{23} = \{(v_3,v_5)\}$
$R^i_{12} = \{(v_1,v_2),(v_1,v_3),(v_3,v_5)\}$	$R^i_{24} = \{(v_3,v_5)\}$
$R^i_{13} = \{(v_1,v_2),(v_1,v_3),(v_3,v_5),(v_4,v_7)\}$	$R^i_{25} = \{(v_3,v_5)\}$
	$R^i_{26} = \{(v_3,v_5)\}$

line 2: v_3 is selected which has maximum indegree $(= 2)$.

line 3: two nodes, v_1 and v_5, are connected with v_3. Here $\deg^-(v_5) > \deg^-(v_1)$. Thus, v_5 is selected.

line 4: $\deg^+(v_3)$ = 2, so loop is continued.

line 5: Edge (v_5, v_3) is deleted from the route R^i_5 (Fig. 5.2 (2))

line 6: v_4 is selected which has maximum indegree $(= 2)$.

line 7: 2 nodes, v_3 and v_6, are connected with v_4. Here $\deg^-(v_6) > \deg^-(v_3)$. Thus, v_6 is selected.

line 4': $\deg^+(v_4)$ = 2, so loop is continued.

line 5': Edge (v_6, v_4) is deleted from the route R^i_6 (Fig. 5.2 (3))

line 6': v_2 is selected which has maximum indegree $(= 1)$.

line 7': one node, v_1, is connected with v_2. Thus, v_2 is selected.

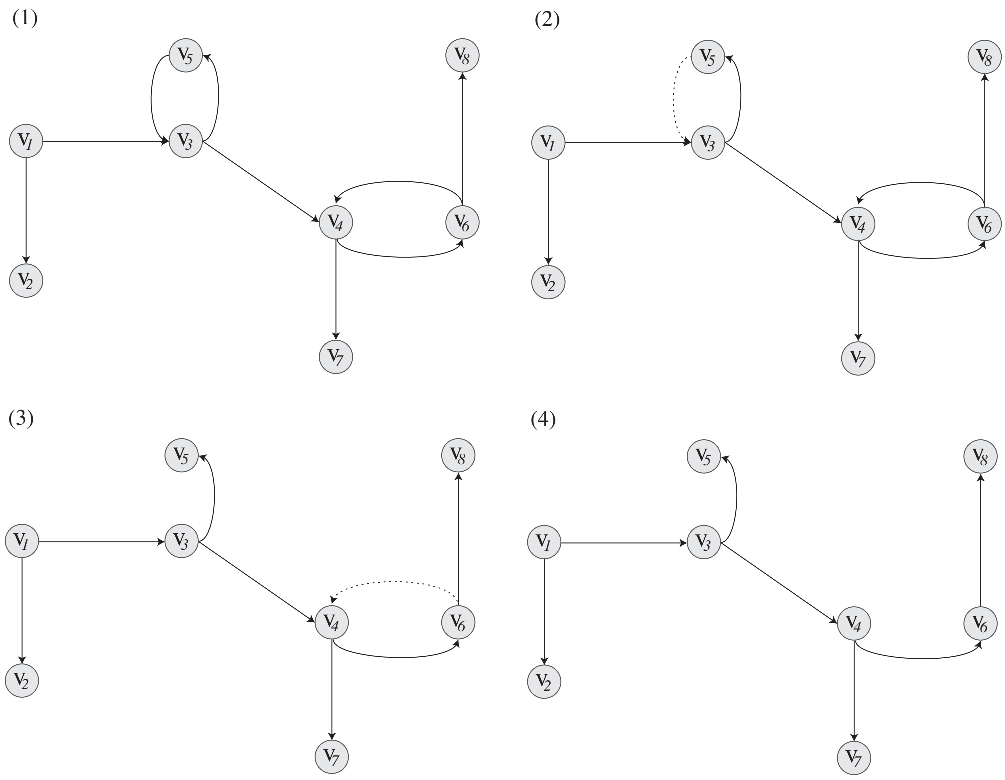


Figure 5.2 – Flow of information i_5.

line 4": $\deg^{+}(v_2) = 1$, so loop is cancelled.

Eventually, the reduced route shown in Fig. 5.2 (4) is obtained.

In this way, all of the routes of information are reduced as shown in Table 5.5.

(3) Generating document flows from information flows
Document flows are generated from the reduced information flows by using algorithms 2 as followings:

line 3: Twenty-five documents ($|\mathbb{I}_A| = 25$) are created as $\mathbb{D}_A = \{D_{<1>}, D_{<2>}, D_{<3>}, \cdots, D_{<26>}\}$. Each document has an information, e.g. $D_{<5>} = \{i_5\}$, $D_{<6>} = \{i_6\}$.

line 5-7: Create route of each document as same with the route of information included in the document.

line 9: 0th document, $D_{<5>}$ is selected as **a**. $R^d_a = \{(v_1, v_2), (v_1, v_3), (v_3, v_4), (v_3, v_5), (v_4, v_6), (v_4, v_7), (v_6, v_8)\}$

line 10: 1st document, $D_{<6>}$ is selected as **b**. $R^d_b = \{(v_1, v_2), (v_1, v_3), (v_3, v_4), (v_3, v_5), (v_4, v_6), (v_4, v_7), (v_6, v_8)\}$

Table 5.5 – Reduced information flows of example A

$R^i_1 = \{(v_1, v_2), (v_1, v_3), (v_3, v_5)\}$	$R^i_{14} = \{(v_3, v_5)\}$
$R^i_2 = \{(v_1, v_2), (v_1, v_3), (v_3, v_5)\}$	$R^i_{15} = \{(v_1, v_2), (v_1, v_3), (v_3, v_4), (v_3, v_5), (v_4, v_7)\}$
$R^i_3 = \{(v_1, v_2), (v_1, v_3), (v_3, v_4), (v_3, v_5), (v_4, v_6), (v_6, v_8)\}$	$R^i_{16} = \{(v_3, v_5)\}$
$R^i_4 = \{(v_1, v_2), (v_1, v_3), (v_3, v_4), (v_3, v_5), (v_4, v_6), (v_6, v_8)\}$	$R^i_{17} = \{(v_5, v_3)\}$
$R^i_5 = \{(v_1, v_2), (v_1, v_3), (v_3, v_4), (v_3, v_5), (v_4, v_6), (v_4, v_7), (v_6, v_8)\}$	$R^i_{18} = \{(v_5, v_3)\}$
$R^i_6 = \{(v_1, v_2), (v_1, v_3), (v_3, v_4), (v_3, v_5), (v_4, v_6), (v_6, v_4), (v_6, v_8), \}$	$R^i_{19} = \{(v_5, v_3)\}$
$R^i_8 = \{(v_1, v_2), (v_1, v_3), (v_3, v_5), (v_4, v_6)\}$	$R^i_{20} = \{(v_3, v_5)\}$
$R^i_9 = \{(v_1, v_2), (v_1, v_3), (v_3, v_5)\}$	$R^i_{21} = \{(v_3, v_5)\}$
$R^i_{10} = \{(v_1, v_2), (v_1, v_3), (v_3, v_5)\}$	$R^i_{22} = \{(v_3, v_5)\}$
$R^i_{11} = \{(v_1, v_2), (v_1, v_3), (v_3, v_5)\}$	$R^i_{23} = \{(v_3, v_5)\}$
$R^i_{12} = \{(v_1, v_2), (v_1, v_3), (v_3, v_5)\}$	$R^i_{24} = \{(v_3, v_5)\}$
$R^i_{13} = \{(v_1, v_2), (v_1, v_3), (v_3, v_4), (v_3, v_5), (v_4, v_7)\}$	$R^i_{25} = \{(v_3, v_5)\}$
	$R^i_{26} = \{(v_3, v_5)\}$

line 11: $R^d_a \cap R^d_b \neq \phi$

line 14: $R^d_a = R^d_b$, so line 15-18 are executed.

line 15: Create a new document $D_{<5,6>} = \{i_5, i_6\}$.

line 16: Document $D_{<5,6>}$ is added for the set of $\mathbb{D}_A$, and the route of document $D_{<5,6>} (= D_{<5>})$ is add for the set of $\mathbb{R}_A$.

line 17: Document $D_{<5>}$ and $D_{<5>}$ are delete from the set of $\mathbb{D}_A$. $R^d_{<5>}$ and $R^d_{<5>}$ are deleted from the set of $\mathbb{R}_A$. Here, $\mathbb{D}_A = \{D_{<1>}, D_{<2>}, \cdots, D_{<26>}, D_{<5,6>}\}$.

line 18: Evaluation function is calculated.

line 35: Goto line 9

line 9': 0th document, $D_{<3>}$ is selected as **a**.

line 10': 1st document, $D_{<4>}$ is selected as **b**.

In this way, the documents are gradually merged. Eventually the below five documents are obtained:

(1) $D_A = \{i_3, i_4, i_5, i_6\}$, $R^d_A = \{(v_1, v_2), (v_1, v_3), (v_3, v_4), (v_3, v_5), (v_4, v_6), (v_4, v_7), (v_6, v_8)\}$

(2) $D_B = \{i_1, i_2, i_9, i_{10}, i_{11}, i_{12}, i_{13}, i_{14}, i_{15}\}$, $R^d_B = \{(v_1, v_2), (v_1, v_3), (v_3, v_5)\}$

(3) $D_C = \{i_{13}, i_{15}\}$, $R^d_C = \{(v_3, v_4), (v_4, v_7)\}$

(4) $D_D = \{i_{16}, i_{17}, i_{18}, i_{19}\}$, $R^d_D = \{(v_5, v_3)\}$

(5) $D_E = \{i_8, i_{14}\}$, $R^d_E = \{(v_4, v_6)\}$

(6) $D_F = \{i_{14}, i_{20}, i_{21}, i_{22}, i_{23}, i_{24}, i_{25}, i_{26}\}$, $R^d_F = \{(v_3, v_5)\}$

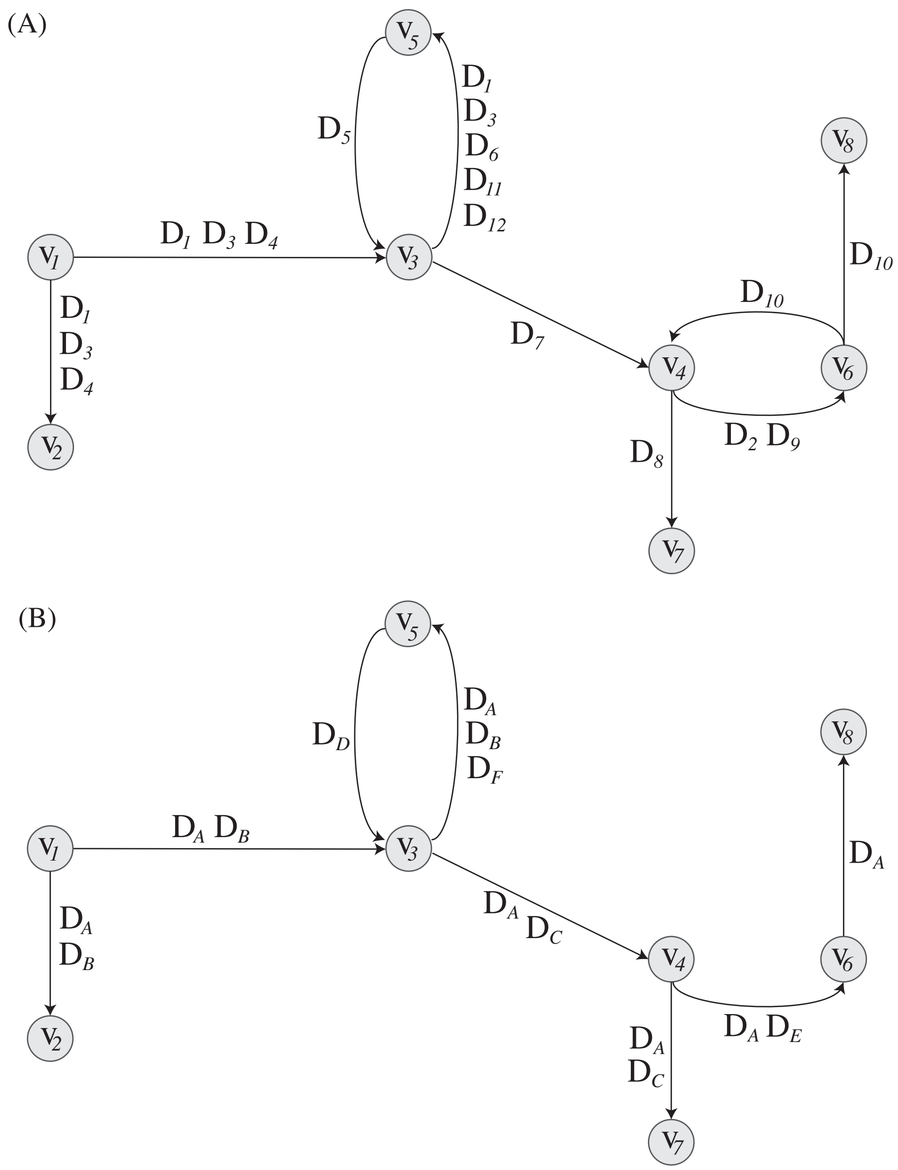


Figure 5.3 – Original and reduced document flows of example A.

Figure 5.3 (A) shows the original document flows and Fig.5.3 (B) shows the reduced document flows. In addition, the number of information transmissions can be deduced as shown in Equation (5.1).

$$T_a = |D_a| \times t_a \tag{5.1}$$

where,

- T_a: Total number of informations transmission of a document a
- D_a: Number of informations of a document a
- t_a: Times of document a transmission in a process

Table 5.6 – The numbers of information transmission of current process and the reduced process in example A

Original process of example A				**Reduced process of example A**			
Document	Number of informations	Times of document transmission	Total number of transmission	Document	Number of informations	Times of document transmission	Total number of transmission
D_1	6	3	18	D_A	4	8	28
D_2	5	1	5	D_B	9	3	27
D_3	7	3	21	D_C	2	2	4
D_4	6	2	12	D_D	4	1	4
D_5	7	1	7	D_E	2	1	2
D_6	6	1	6	D_F	8	1	2
D_7	6	1	6	Total number of information transmissions of all documents			73
D_8	6	1	6				
D_9	5	1	5				
D_{10}	4	2	8				
D_{11}	4	1	4				
D_{12}	4	1	4				
Total number of information transmissions of all documents			102				

Table 5.6 shows the numbers of information transmissions of current process and the reduced process in example A. In the table, number of information of a document, times of document transmission, and total number of transmission are shown. We can see that the number of documents is decreased from ten to six. The flow of document from shipping agent (v_6) to forwarding agent (v_4) is eliminated due to reduction. Futhermore, the number of information transmissions is also decreased from one-hundred-two times to seventy-three times (28.4%).

5.2.2 Example B: An export process from Lao PDR to Thailand

Seven organizations: (1) Exporter, (2) Bank, (3) Lao PDR custom, (4) Lao PDR immigration, (5) Thailand immigration, (6) Importer, and (7) Thailand custom are related to the process. In the process, five types of documents: (1) invoice, (2) packing list, (3) personal passport, (4) international transport permit, and (5) bill of lading are used.

Table 5.7 shows notation representing organizations in example B.

In Fig. 5.4 (A), the document flows of example B are shown. Each node stands for

Table 5.7 – Notation of organizations in example B

Organizations	Notations
Exporter	v_{10}
Bank	v_{11}
Lao PDR's custom	v_{12}
Lao PDR's immigration	v_{13}
Thailand's immigration	v_{14}
Importer	v_{15}
Thailand's custom	v_{16}

organization and each arrow stands for a path of document flow. In Fig. 5.4 (B), the document flows are represented by using a graph structure with the symbols in Table 5.1 and 5.7. The process in Fig. 5.4 can be described as formulae in Table 5.8 by using

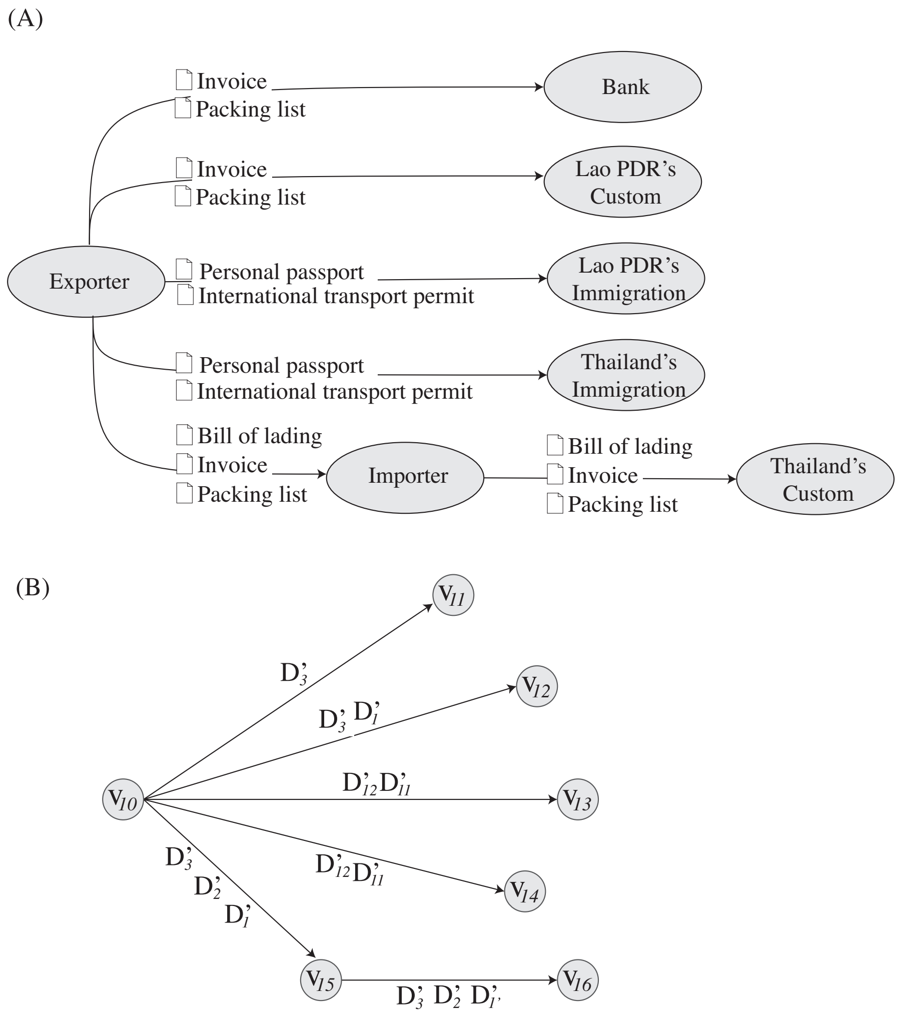


Figure 5.4 – Document flows of example B.

the mathematical model shown in chapter 3.

Table 5.8 – A Mathematical model of example B

$\mathbb{P}_B = (\mathbb{G}_B, \mathbb{D}_B, \mathbb{I}_B, \mathbb{Q}_B, \mathbb{R}_B)$
$\mathbb{G}_B = (\mathbb{V}_B, \mathbb{E}_B)$
$\mathbb{V}_B = \{\mathrm{v}_{10}, \mathrm{v}_{11}, \mathrm{v}_{12}, \mathrm{v}_{13}, \mathrm{v}_{14}, \mathrm{v}_{15}, \mathrm{v}_{16}\}$
$\mathbb{E}_B = \{(\mathrm{v}_{10}, \mathrm{v}_{11}), (\mathrm{v}_{10}, \mathrm{v}_{12}), (\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{14}), (\mathrm{v}_{10}, \mathrm{v}_{15}), (\mathrm{v}_{15}, \mathrm{v}_{16})\}$
$\mathbb{D}_B = \{\mathrm{D}_{1'}, \mathrm{D}_{2'}, \mathrm{D}_{3'}, \mathrm{D}_{11'}, \mathrm{D}_{12'}\}$
$\mathrm{D}_{1'} = \{\mathrm{i}_1, \mathrm{i}_2, \mathrm{i}_5, \mathrm{i}_6, \mathrm{i}_3, \mathrm{i}_4, \mathrm{i}_7\}$
$\mathrm{D}_{2'} = \{\mathrm{i}_5, \mathrm{i}_6, \mathrm{i}_3, \mathrm{i}_4, \mathrm{i}_8\}$
$\mathrm{D}_{3'} = \{\mathrm{i}_9, \mathrm{i}_{10}, \mathrm{i}_{11}, \mathrm{i}_{12}, \mathrm{i}_{13}, \mathrm{i}_8, \mathrm{i}_{14}\}$
$\mathrm{D}_{11'} = \{\mathrm{i}_{20}, \mathrm{i}_{21}, \mathrm{i}_{22}, \mathrm{i}_{23}\}$
$\mathrm{D}_{12'} = \{\mathrm{i}_{24}, \mathrm{i}_{25}, \mathrm{i}_{26}, \mathrm{i}_{14}\}$
$\mathbb{I}_B = \{\mathrm{i}_1, \mathrm{i}_2, \mathrm{i}_5, \mathrm{i}_6, \mathrm{i}_3, \mathrm{i}_4, \mathrm{i}_7, \mathrm{i}_8, \mathrm{i}_9, \mathrm{i}_{10}, \mathrm{i}_{11}, \mathrm{i}_{12}, \mathrm{i}_{13}, \mathrm{i}_{14}, \mathrm{i}_{20}, \mathrm{i}_{21}, \mathrm{i}_{22}, \mathrm{i}_{23}, \mathrm{i}_{24}, \mathrm{i}_{25}, \mathrm{i}_{26}\}$
$\mathbb{Q}_B = \{\mathrm{q}_{10}, \mathrm{q}_{11}, \mathrm{q}_{12}, \mathrm{q}_{13}, \mathrm{q}_{14}, \mathrm{q}_{15}, \mathrm{q}_{16}\}$
$\mathbb{R}_B = \{\mathrm{R}^{\mathrm{d}}_{1'}, \mathrm{R}^{\mathrm{d}}_{2'}, \mathrm{R}^{\mathrm{d}}_{3'}, \mathrm{R}^{\mathrm{d}}_{11'}, \mathrm{R}^{\mathrm{d}}_{12'}\}$
$\mathrm{R}^{\mathrm{d}}_{1'} = \{(\mathrm{v}_{10}, \mathrm{v}_{11}), (\mathrm{v}_{10}, \mathrm{v}_{12}), (\mathrm{v}_{10}, \mathrm{v}_{15}), (\mathrm{v}_{15}, \mathrm{v}_{16})\}$
$\mathrm{R}^{\mathrm{d}}_{2'} = \{(\mathrm{v}_{10}, \mathrm{v}_{15}), (\mathrm{v}_{15}, \mathrm{v}_{16})\}$
$\mathrm{R}^{\mathrm{d}}_{3'} = \{(\mathrm{v}_{10}, \mathrm{v}_{11}), (\mathrm{v}_{10}, \mathrm{v}_{12}), (\mathrm{v}_{10}, \mathrm{v}_{15}), (\mathrm{v}_{15}, \mathrm{v}_{16})\}$
$\mathrm{R}^{\mathrm{d}}_{11'} = \{(\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{14})\}$
$\mathrm{R}^{\mathrm{d}}_{12'} = \{(\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{14})\}$

(1) Converting document flows to information flows

Routes of information are generated from the routes of document shown in Fig. 5.4 by using the equation (4.1) on page 22. The generated routes of information are shown in Table 5.9.

Table 5.9 – Routes of information of example B

$\mathrm{R}^{\mathrm{i}}_{1} = \{(\mathrm{v}_{10}, \mathrm{v}_{11}), (\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{15}), (\mathrm{v}_{15}, \mathrm{v}_{16})\}$	$\mathrm{R}^{\mathrm{i}}_{12} = \{(\mathrm{v}_{10}, \mathrm{v}_{11}), (\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{15}) (\mathrm{v}_{15}, \mathrm{v}_{16})\}$
$\mathrm{R}^{\mathrm{i}}_{2} = \{(\mathrm{v}_{10}, \mathrm{v}_{11}), (\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{15}), (\mathrm{v}_{15}, \mathrm{v}_{16})\}$	$\mathrm{R}^{\mathrm{i}}_{13} = \{(\mathrm{v}_{10}, \mathrm{v}_{11}), (\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{15}) (\mathrm{v}_{15}, \mathrm{v}_{16})\}$
$\mathrm{R}^{\mathrm{i}}_{3} = \{(\mathrm{v}_{10}, \mathrm{v}_{11}), (\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{15}), (\mathrm{v}_{15}, \mathrm{v}_{16})\}$	$\mathrm{R}^{\mathrm{i}}_{14} = \{(\mathrm{v}_{10}, \mathrm{v}_{11}), (\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{14})(\mathrm{v}_{10}, \mathrm{v}_{15}), (\mathrm{v}_{15}, \mathrm{v}_{16})\}$
$\mathrm{R}^{\mathrm{i}}_{4} = \{(\mathrm{v}_{10}, \mathrm{v}_{11}), (\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{15}), (\mathrm{v}_{15}, \mathrm{v}_{16})\}$	$\mathrm{R}^{\mathrm{i}}_{20} = \{(\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{14})\}$
$\mathrm{R}^{\mathrm{i}}_{5} = \{(\mathrm{v}_{10}, \mathrm{v}_{11}), (\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{15}), (\mathrm{v}_{15}, \mathrm{v}_{16})\}$	$\mathrm{R}^{\mathrm{i}}_{21} = \{(\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{14})\}$
$\mathrm{R}^{\mathrm{i}}_{6} = \{(\mathrm{v}_{10}, \mathrm{v}_{11}), (\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{15}), (\mathrm{v}_{15}, \mathrm{v}_{16})\}$	$\mathrm{R}^{\mathrm{i}}_{22} = \{(\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{14})\}$
$\mathrm{R}^{\mathrm{i}}_{7} = \{(\mathrm{v}_{10}, \mathrm{v}_{11}), (\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{15}), (\mathrm{v}_{15}, \mathrm{v}_{16})\}$	$\mathrm{R}^{\mathrm{i}}_{23} = \{(\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{14})\}$
$\mathrm{R}^{\mathrm{i}}_{8} = \{(\mathrm{v}_{10}, \mathrm{v}_{11}), (\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{15}), (\mathrm{v}_{15}, \mathrm{v}_{16})\}$	$\mathrm{R}^{\mathrm{i}}_{24} = \{(\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{14})\}$
$\mathrm{R}^{\mathrm{i}}_{9} = \{(\mathrm{v}_{10}, \mathrm{v}_{11}), (\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{15}), (\mathrm{v}_{15}, \mathrm{v}_{16})\}$	$\mathrm{R}^{\mathrm{i}}_{25} = \{(\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{14})\}$
$\mathrm{R}^{\mathrm{i}}_{10} = \{(\mathrm{v}_{10}, \mathrm{v}_{11}), (\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{15}), (\mathrm{v}_{15}, \mathrm{v}_{16})\}$	$\mathrm{R}^{\mathrm{i}}_{26} = \{(\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{14})\}$
$\mathrm{R}^{\mathrm{i}}_{11} = \{(\mathrm{v}_{10}, \mathrm{v}_{11}), (\mathrm{v}_{10}, \mathrm{v}_{13}), (\mathrm{v}_{10}, \mathrm{v}_{15}), (\mathrm{v}_{15}, \mathrm{v}_{16})\}$	

(2) Reducing information flows

The generated information flows are reduced by using algorithm 1 as same as example A. For example, $\mathrm{R}^{\mathrm{i}}_{14}$ is reduced as followings:

line 1: $\deg^+(v_2) = 1(>0)$, $\deg^+(v_3) = 1(>0)$, $\deg^+(v_4) = 1(>0)$, $\deg^+(v_5) = 1(>0)$, $\deg^+(v_6) = 1(>0)$, and $\deg^+(v_7) = 1(>0)$ so loop is continued.

line 2: v_2 is selected which has maximum indegree $(=1)$.

line 3: Here only node v_1 is connected with node v_2 ($\deg^-(v_1) = 1$). Thus, v_1 is selected.

line 4: $\deg^+(v_1) = 0$, so loop is cancelled.

In this example, all nodes of R^i_{14} have indegree less than 1 ($\deg^+(v_2) = 1(>0)$, $\deg^+(v_3) = 1(>0)$, $\deg^+(v_4) = 1(>0)$, $\deg^+(v_5) = 1(>0)$, $\deg^+(v_6) = 1(>0)$, and $\deg^+(v_7) = 1(>0)$) which means R^i_{14} have already reduced. In this way, all of the routes of information are reduced as shown in Table 5.10.

Table 5.10 – Reduced information flows of example B

$R^i_1 = \{(v_{10}, v_{11}), (v_{10}, v_{13}), (v_{10}, v_{15}), (v_{15}, v_{16})\}$	$R^i_{12} = \{(v_{10}, v_{11}), (v_{10}, v_{13}), (v_{10}, v_{15})$ $(v_{15}, v_{16})\}$
$R^i_2 = \{(v_{10}, v_{11}), (v_{10}, v_{13}), (v_{10}, v_{15}), (v_{15}, v_{16})\}$	$R^i_{13} = \{(v_{10}, v_{11}), (v_{10}, v_{13}), (v_{10}, v_{15})$ $(v_{15}, v_{16})\}$
$R^i_3 = \{(v_{10}, v_{11}), (v_{10}, v_{13}), (v_{10}, v_{15}), (v_{15}, v_{16})\}$	$R^i_{14} = \{(v_{10}, v_{11}), (v_{10}, v_{13}), (v_{10}, v_{13}),$ $(v_{10}, v_{14})(v_{10}, v_{15}), (v_{15}, v_{16})\}$
$R^i_4 = \{(v_{10}, v_{11}), (v_{10}, v_{13}), (v_{10}, v_{15}), (v_{15}, v_{16})\}$	$R^i_{20} = \{(v_{10}, v_{13}), (v_{10}, v_{14})\}$
$R^i_5 = \{(v_{10}, v_{11}), (v_{10}, v_{13}), (v_{10}, v_{15}), (v_{15}, v_{16})\}$	$R^i_{21} = \{(v_{10}, v_{13}), (v_{10}, v_{14})\}$
$R^i_6 = \{(v_{10}, v_{11}), (v_{10}, v_{13}), (v_{10}, v_{15}), (v_{15}, v_{16})\}$	$R^i_{22} = \{(v_{10}, v_{13}), (v_{10}, v_{14})\}$
$R^i_7 = \{(v_{10}, v_{11}), (v_{10}, v_{13}), (v_{10}, v_{15}), (v_{15}, v_{16})\}$	$R^i_{23} = \{(v_{10}, v_{13}), (v_{10}, v_{14})\}$
$R^i_8 = \{(v_{10}, v_{11}), (v_{10}, v_{13}), (v_{10}, v_{15}), (v_{15}, v_{16})\}$	$R^i_{24} = \{(v_{10}, v_{13}), (v_{10}, v_{14})\}$
$R^i_9 = \{(v_{10}, v_{11}), (v_{10}, v_{13}), (v_{10}, v_{15}), (v_{15}, v_{16})\}$	$R^i_{25} = \{(v_{10}, v_{13}), (v_{10}, v_{14})\}$
$R^i_{10} = \{(v_{10}, v_{11}), (v_{10}, v_{13}), (v_{10}, v_{15}), (v_{15}, v_{16})\}$	$R^i_{26} = \{(v_{10}, v_{13}), (v_{10}, v_{14})\}$
$R^i_{11} = \{(v_{10}, v_{11}), (v_{10}, v_{13}), (v_{10}, v_{15}), (v_{15}, v_{16})\}$	

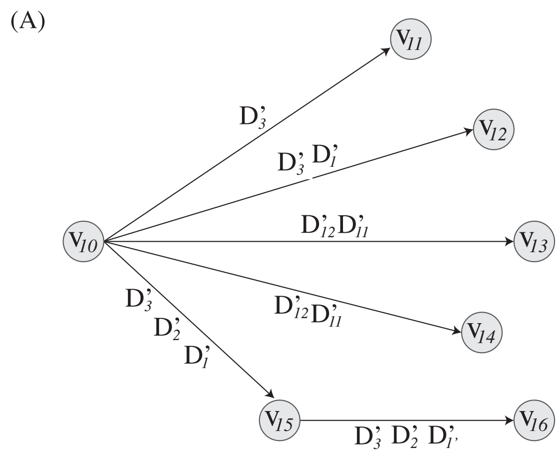
(3) Generating document flows from information flows
Document flows are generated from the reduced information flows by using algorithms 2 as same as example A. The two documents shown below are obtained.

(1) $D_G = \{i_1, i_2, i_3, i_4, i_5, i_6, i_7, i_8, i_9, i_{10}, i_{11}, i_{12}, i_{13}, i_{14}\}$,
$R^d_G = \{(v_{10}, v_{11}), (v_{10}, v_{12}), (v_{10}, v_{15}), (v_{10}, v_{16})\}$

(2) $D_H = \{i_{14}, i_{20}, i_{21}, i_{22}, i_{23}, i_{24}, i_{25}, i_{26}\}$, $R^d_H = \{(v_{10}, v_{13}), (v_{10}, v_{14})\}$

Figure 5.5 (A) shows the original document flows and Fig. 5.5 (B) shows the reduced document flows.

Table 5.11 shows the numbers of information transmissions of current process and the reduced process in example B by using the equation (5.1) on page 37. In the table, number of information of a document, times of document transmission, and total



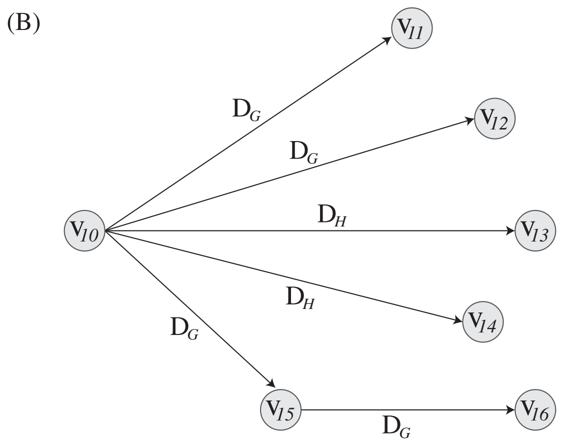


Figure 5.5 – Original and reduced document flows of example B.

number of transmission are shown. According to the table, the number of documents decreases from five to two. Furthermore, the number of information transmissions is also decreased from seventy-eight times to seventy times (10.3%).

5.2.3 Discussion

In this paper, the algorithms used in the supporting system for reducing document flows in international trade transaction processes are proposed. First, a mathematical model has been defined for describing document flows in international trade transaction processes. Then, two algorithms have been proposed base on the mathematical model; one is reducing information flows, and the other is generating document flows from information flows.

Two examples are shown to discuss the ability of the proposed model and algorithms. The numbers of information transmissions are decreased one-hundred-two times to seventy-three times (28.4%) in example A and from seventy-eight times to seventy times (10.3%) in example B, respectively. They seem that the the proposed algorithms

Table 5.11 – The numbers of information transmission of current process and the reduced process in example B

Original process of example B				**Reduced process of example B**			
Document	Number of informations	Times of document transmission	Total number of transmission	Document	Number of informations	Times of document transmission	Total number of transmission
D'$_1$	7	4	28	D_G	14	4	56
D'$_2$	5	2	10	D_H	7	2	14
D'$_3$	6	4	24	Total number of information transmissions of all documents			70
D'$_{11}$	4	2	8				
D'$_{12}$	4	2	8				
Total number of information transmissions of all documents			78				

contribute to reduce redundancies in the paperworks.

By using the proposed mathematical model, it is expected that different countries' systems can be merged as one-system. For instance, process of example A ($\mathbb{P}_A$) and example process of example B ($\mathbb{P}_B$) can be considered as a process from Lao PDR to Malaysia via Thailand ($\mathbb{P}_{BA}$) as shown below:

$$\mathbb{P}_{BA} = (\mathbb{G}_{BA}, \mathbb{D}_{BA}, \mathbb{I}_{BA}, \mathbb{Q}_{BA}, \mathbb{R}_{BA})$$
$$\mathbb{G}_{BA} = (\mathbb{V}_B \cup \mathbb{V}_A, \mathbb{E}_B \cup \mathbb{E}_A)$$
$$\mathbb{D}_{BA} = \mathbb{D}_B \cup \mathbb{D}_A$$
$$\mathbb{R}_{BA} = \mathbb{R}_B \cup \mathbb{R}_A$$

$v_1 \in \mathbb{V}_A$ and $v_{15} \in \mathbb{V}_B$ are merged as v_1 because they stand for the same organization. $v_2 \in \mathbb{V}_A$ and $v_{16} \in \mathbb{V}_B$ are merged as v_2 because both of them stand for 'Thailand's custom'. Figure 5.6 shows the merged processes.

Figure 5.7 shows the actual process of international trade transaction from Lao PDR to Malaysia via Thailand ($\mathbb{P}_{\texttt{L\_Th\_M}}$). Table 5.12 shows informations which are received by each node. This table shows that all of the organizations in the merged process can get the same informations with the actual process. However, the size of network of the merged process is larger than the size of network of the current process. In addition, more numbers of informations are transmitted in the merged process. In Table 5.12, the informations indicated by bold fonts are informations which are not transmitted in the actual process. Optimizing methods should be considered in the future works.

5.3 Experiment 2

In this experiment, it is conducted for confirming the flexibility of the proposed system. When reducing document flows, the requirements of system designers must be considered. For example, someone could want to reduce the number of documents in a process, and the other one could want to reduce the number of informations included in a document. The proposed system can have several evaluations in accordance

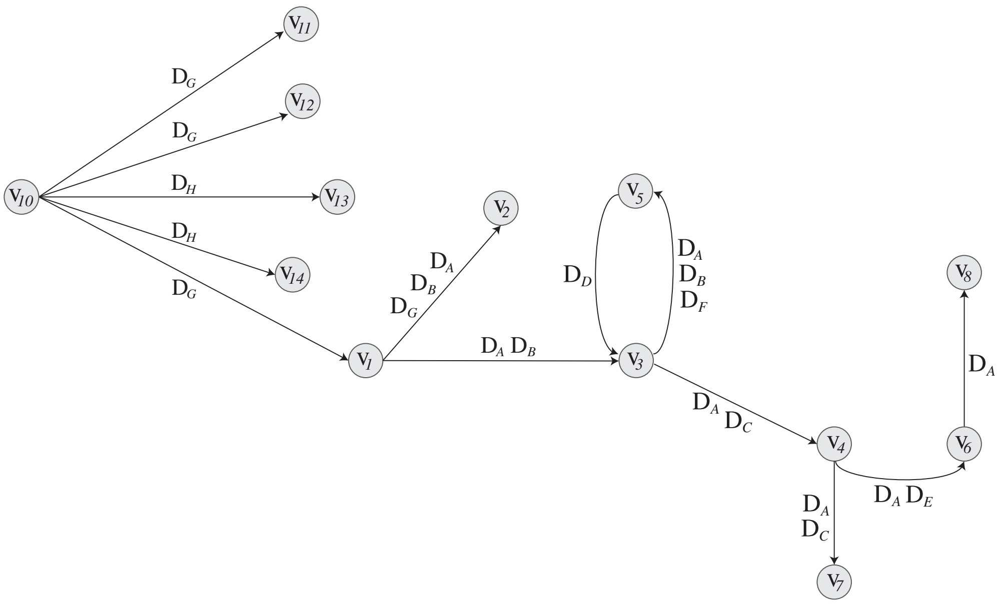


Figure 5.6 – Document flows of the merged process.

Table 5.12 – Information getten by each node

Node	Merged process	Actual prcess
v_1	$i_1, i_2, i_5, i_6, i_7, i_3, i_4, i_8, i_9, i_{10}, i_{11}, i_{12}, i_{13}, i_{14}$	
v_2	$i_1, i_2, i_5, i_6, i_3, i_4, i_7, i_8, i_9, i_{10}, i_{11}, i_{12}, i_{13}, \mathbf{i_{15}}, i_{14}$	$i_1, i_2, i_5, i_6, i_3, i_4, i_8, i_7, i_9, i_{10}, i_{11}, i_{12}, i_{13}, i_{14}$
v_3	$i_1, i_2, i_5, i_6, i_3, i_4, i_7, i_9, i_{10}, i_{11}, i_{12}, i_{13}, \mathbf{i_{15}}, i_{14}, \mathbf{i_{16}}, \mathbf{i_{17}}, \mathbf{i_{18}}, \mathbf{i_{19}}$	$i_1, i_2, i_5, i_6, i_3, i_4, i_7, i_8, i_9, i_{10}, i_{11}, i_{12}, i_{13}, i_{14}$
v_4	$\mathbf{i_5, i_6, i_3, i_{4,13}, i_{15}}$	
v_5	$\mathbf{i_5, i_6, i_3, i_4, i_1, i_2, i_9, i_{10}, i_{11}, i_{12}, i_{13}, i_{15}, i_{14}, i_{20}, i_{21}, i_{22}, i_{23}, i_{24}, i_{25}, i_{26}, i_{14}}$	
v_6	$\mathbf{i_5, i_6, i_3, i_4, i_8, i_{14}}$	
v_7	$i_5, i_6, i_3, i_4, i_{13}, i_{15}$	$i_5, i_6, i_3, i_4, i_{13}, i_{15}$
v_8	$\mathbf{i_5, i_6, i_3, i_4}$	
v_{10}		
v_{11}	$i_1, i_2, i_5, i_6, i_7, i_3, i_4, i_8, i_9, i_{10}, i_{11}, i_{12}, i_{13}, i_{14}$	$i_1, i_2, i_5, i_6, i_7, i_3, i_4, i_8, i_9, i_{10}, i_{11}, i_{12}, i_{13}, i_{14}$
v_{12}	$i_1, i_2, i_5, i_6, i_7, i_3, i_4, i_8, i_9, i_{10}, i_{11}, i_{12}, i_{13}, i_{14}$	$i_1, i_2, i_5, i_6, i_3, i_4, i_7, i_8, i_9, i_{10}, i_{11}, i_{12}, i_{13}, i_{14}$
v_{13}	$i_{20}, i_{21}, i_{22}, i_{23}, i_{24}, i_{25}, i_{26}, i_{14}$	$i_{20}, i_{21}, i_{22}, i_{23}, i_{24}, i_{25}, i_{26}, i_{14}$
v_{14}	$i_{20}, i_{21}, i_{22}, i_{23}, i_{24}, i_{25}, i_{26}, i_{14}$	$i_{20}, i_{21}, i_{22}, i_{23}, i_{24}, i_{25}, i_{26}, i_{14}$

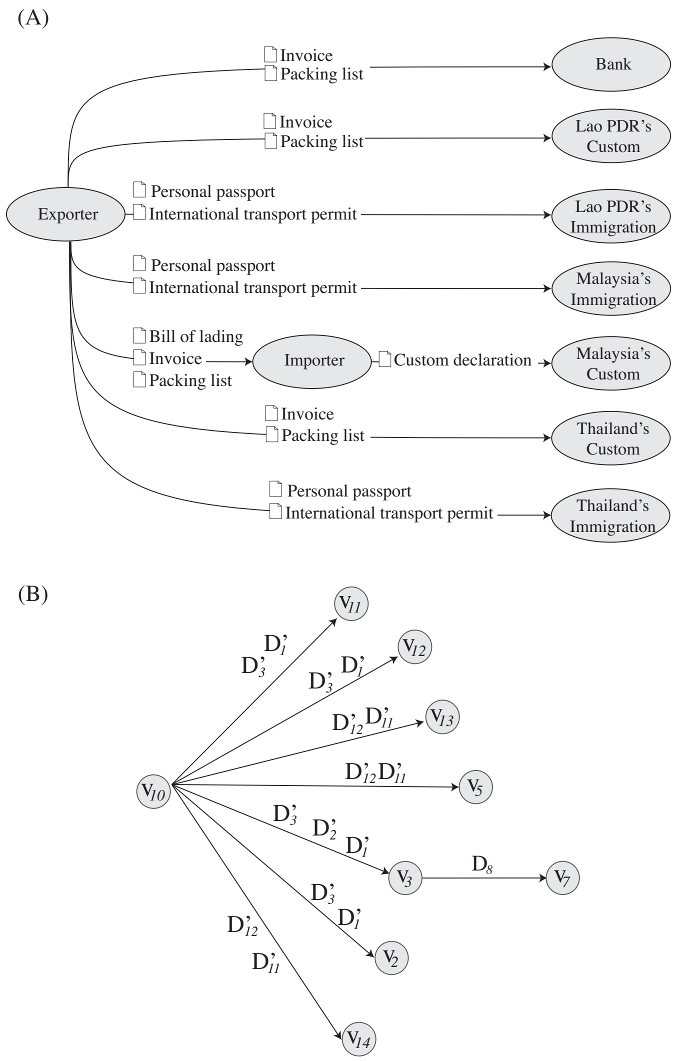


Figure 5.7 – Document flows of the actual process.

with the requirements of the system designers. In order to show the flexibility of the proposed system, a result of experiment was shown. The evaluation functions in the experiment, two types of the redundancy of paperwork processes are used as criteria; (1) redundancy of sharing information and (2) redundancy of using documents. By using the functions, they have a trade-off relationship. Two different situations of reducing redundancy in paperworks process are investigated; (1) designer place emphasis on reducing informations in a document and (2) designer place emphasis on reducing number of documents in the process.

A mechanism is proposed for generating document flows. This mechanism has several evaluation functions, and can switch the function in accordance with the designers' requirements. The proposed mechanism for generating document flows from information flows is shown below:

(1) Each information in the process is arranged on a document, that is the number of documents become same as the number of informations in the process, and route of document is same as the route of information that is included in the document.

(2) For all combinations of a pair of documents, the below sub procedure is conducted.

(2.1) Check if their routes have a common part. If they have, do (2.2).

(2.2) Calculate the evaluation value of the document flows when the two documents are merged.

(3) If there are one or more pairs of documents, merge a pair of documents as the evaluation value of the document flows become minimum, and repeat (2) and (3).

In the procedure, an evaluation function for calculating evaluation value is used. This evaluation function is selected based on the requirements of system designers. In the proposed system, two types of redundancy of paperwork processes are considered; (1) redundancy of sharing informations and (2) redundancy of using documents. The details are described in the next section.

(1) Redundancy of sharing informations
Each organization uses some documents. A document contains several informations. All of them are not particularly used in all of the organization received the document. These unused informations can be considered as redundant one for the organization. To calculate the redundancy, the total number of required informations of all organizations and the total number of obtained information of all organizations are used. The redundancy of sharing informations in document flows can be calculated as shown in equation (5.2).

$$f_1(\mathbb{P}_X) = \left(\frac{\sum\limits_{\mathrm{q}_n \epsilon \mathbb{Q}_X} |\mathrm{q}_n|}{\sum\limits_{(\mathrm{v}_m,\mathrm{v}_n)\epsilon \mathrm{R}^d_a} \sum\limits_{\mathrm{D}_a \epsilon \mathbb{D}_X} \sum\limits_{\mathrm{v}_n \epsilon \mathbb{V}_X} |\mathrm{D}_{a,\mathrm{v}_n}|} \right) \tag{5.2}$$

where,

- $\mathbb{P}_X$: Process of paperworks in an international trade transaction named X
- q_n: A set of informations that required on node n
- $\mathbb{V}_X$: A set of nodes which represent organizations in process X

- v_m: A source organization m
- v_n: A source organization n
- $\mathrm{R}^{\mathrm{d}}_a$: A route of document a
- $\mathbb{D}_X$: A set of documents used in process X
- D_a : A set of informations included in a document a

(2) Redundancy of using documents in paperworks processes
The total number of documents in a paperworks process is used for representing the redundancy of using documents. The redundancy of using documents as shown in equation (5.3)

$$f_2(\mathbb{D}_X) = \frac{1}{|\mathbb{D}_X|} \tag{5.3}$$

where,

- $\mathbb{D}_X$: A set of documents that used in process X

Finally, the evaluation value of a paperworks process is calculated as shown in equation (5.4) .

$$F(\mathbb{P}_X) = \alpha f_1(\mathbb{P}_X) + \beta f_2(\mathbb{D}_X) \tag{5.4}$$

α and β are the weight to decide which redundancy should be focused on. The range of weight α and β is between 0 to 1. The summation of three weights is $1(\alpha + \beta = 1)$. For example, when the redundancy of sharing information is focused. The weight can be set as $\alpha = 0.8$ and $\beta = 0.2$. In order to identify the best trade-offs relationship between each criterion, the weight can be changed in the evaluation function.

5.3.1 Example

An international trade transaction process is used for an example. This process has seven organizations; (1) Buyer, (2) Seller, (3) Freight forwarder, (4) Custom broker of destination, (5) Custom of destination, (6) Custom broker of origin, and (7) Customs of origin. In this process, four types of informations are transmitted among the organizations. Table 5.13 and 5.14 show notations which represent organizations and informations.

A process of generating document flows from information flows are shown below.

Table 5.13 – Organizations

Organization	Notation
Buyer	v_1
Seller	v_2
Freight forwarder	v_3
Custom broker of destination	v_4
Custom of destination	v_5
Custom broker of original	v_6
Custom of original	v_7

Table 5.14 – Information of the experiment

Information	Notation
Seller name	i_a
Purchase order number	i_b
Bill of lading number	i_c
Gross weight	i_d

(1) Four documents which included one information are created; D_a (includes information a, the route is R_a^d), D_b (includes information b, the route is R_b^d), D_c (includes information c, the route is R_c^d), and D_d (includes information d, the route is R_d^d). Figure 5.8 shows the initial document flows. Figure 5.8 (A) shows the route of document a, Fig. 5.8 (B) shows the route of document b, Fig. 5.8 (C) shows the route of document c, and Fig. 5.8 (D) shows the route of document d, respectively.

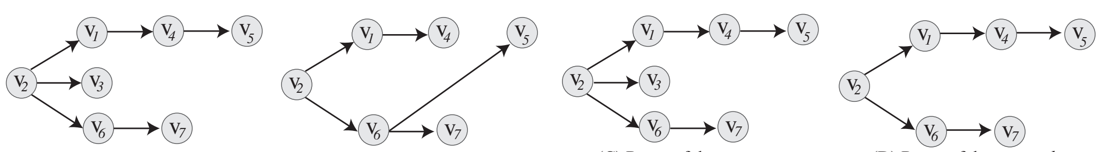


Figure 5.8 – Initial document flows of the example.

(2) Six pairs of documents are found; pair of $a-b$, $a-c$, $a-d$, $b-c$, $b-d$, and $c-d$.

(2.1) R_d^a and R_b^d, R_d^a and R_c^d, R_a^d and R_d^d, R_b^d and R_c^d, R_b^d and R_d^d, and R_c^d and R_d^d have a common paths.

(2.2) The evaluation values when the above pairs are merged are calculated ($\alpha = 0.8, \beta = 0.2$). The results are shown below table:

(3) The pair of R_c^d and R_d^d has the maximum evaluation value. Thus, the D_c and D_d

Table 5.15 – Merged pair and evaluation values

Merged pair	Evaluation values
R_a^d and R_b^d	0.631
R_a^d and R_c^d	0.657
R_a^d and R_d^d	0.633
R_b^d and R_c^d	0.631
R_b^d and R_d^d	0.631
R_c^d and R_d^d	**0.684**

are merged. Now, there are three documents, $D_{<c,d>}$, D_a, and D_b, then go to the step (3). The step (2) and (3) are repeated until cannot find the maximum of the evaluation value of the merged document. Other evaluation functions are calculated in the same way.

5.3.2 Results

In this section, results of an experiment which was conducted for evaluating the proposed mechanism are shown. The initial document flows, which shown in Fig. 5.8 were used for the experiment. The experiment is conducted under two conditions as shown in Table 5.16.

Table 5.16 – Weights of the conditions

Conditions	Weights
1	$\alpha = 0.8, \beta = 0.2$
2	$\alpha = 0.2, \beta = 0.8$

We can consider the experiments under these conditions as situations:

- Situation 1: The designer place emphasis on reducing informations in a document.
- Situation 2: The designer place emphasis on reducing number of documents in the process.

These two situations have a trade-off relationship. If we want to minimize the number of informations included in a document thus the number of documents should be increased. On the other hand, if we want to minimize the number of documents in a paperworks process thus the number of informations included in a document should be decreased. Thus, different answer must be obtained under these conditions. By following the proposed method, two document flows are generated; (1) Document flow A (under condition 1), (2) Document flow B (under condition 2), as shown in Fig. 5.9. Document flow A included three documents; $D_{<c-d>}$, D_a, and D_b. Document flow

B included two documents; $D_{<a-c-d>}$ and D_b.

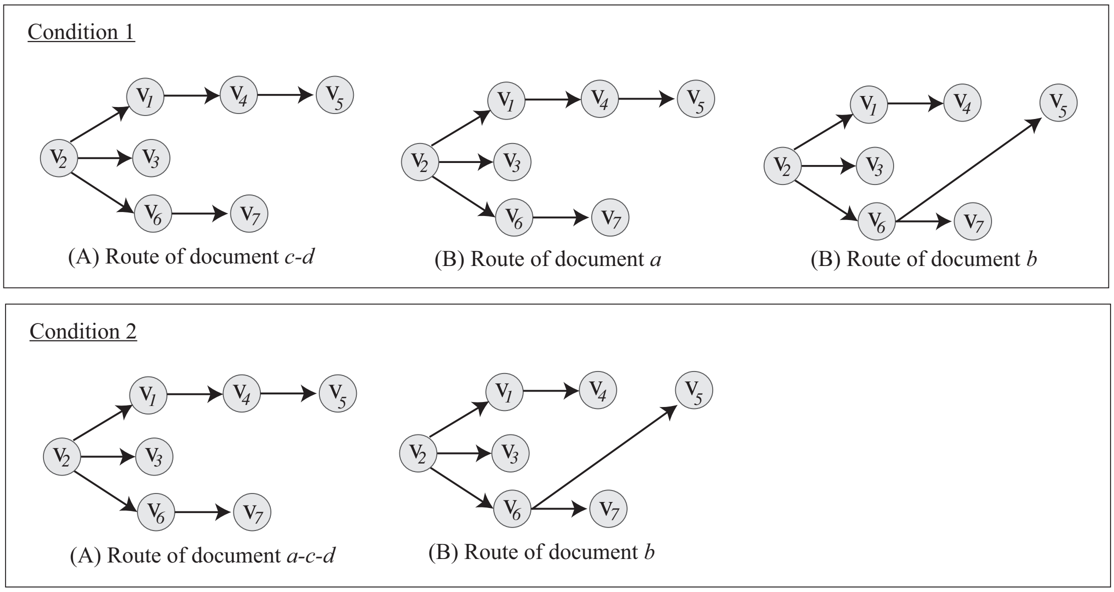


Figure 5.9 – Generating document flows of the example.

Table 5.17 shows a summary of the results. In the table, the second column shows the return value of f_1 (redundancies of sharing informations), the third column shows the return value of f_2 (redundancies of using documents), and the last column shows the evaluation values (F), respectively.

Table 5.17 – Results of the experiment

Document flow	Redundancies of sharing informations (f_1)	Redundancies of using documents (f_2)	Evaluation values (F)
A (Condition 1)	0.773	0.333	0.684
B (Condition 2)	0.708	0.500	0.542

As we can see from the table, under condition 1, Document flow A is better than Document flow B from aspect of redundancies of sharing informations $(0.773 > 0.708)$. Under the condition 2, Document flow B is better than Document flow A from aspect of redundancies of using documents $(0.500 > 0.333)$. From the aspect of the evaluation value, Document flow A is better than Document flow B.

These results confirm that we can adjust the weights of the evaluation function as a condition for generating document flows in accordance with the designers' requirements. Moreover, by arranging informations into a document, they seem that the proposed mechanism can re-design document format.

5.3.3 Discussion

In this section, a new mechanism for optimizing paperworks is proposed. The mechanism can have several evaluations in accordance with the requirements of the system designers. In order to show the usages of proposed mechanism, a result of experiment was shown. The evaluation functions in the experiment, two types of the redundancy of paperwork processes are used as criteria; (1) redundancy of sharing information and (2) redundancy of using documents. By using the functions, they have a trade-off relationship. As a result, the best document flows were generated in accordance with the requirements of system designers. A simple example is shown which have only two sub-evaluation values. However, in actual situations, we have to consider more complex situations that have more compositive requirements and documents. We have to confirm that the proposed mechanism works well in such complex situation in the future.

5.4 Conclusion

In this chapter, two experiments are conducted for investigating the performance of the proposed system. Examples of international trade transaction processes in ASEAN are shown to discuss the abilities of the proposed system. In the first experiment, the total number of information transmissions is compared between original processes and the reduced processes.

In the second experiment, a new mechanism for optimizing paperworks is proposed for generating document flows. The mechanism can have several evaluations in accordance with the requirements of the system designers. In the function, two types of the redundancy of paperwork processes are used as criteria. By changing the value of the weights in the function, the redundancy of paperwork process can be estimated from the two perspectives of (1) redundancy of sharing information and (2) redundancy of using documents in paperwork processes.

6 Conclusions and Future directions

6.1 Conclusions

In this paper, international trade transaction processes can be considered as systems consisting of sub-systems designed by each country for international trades. Each sub-system has designed based on their own concept, and it makes the whole-system complex. Thus, international trade transaction processes can be shown as networks. A supporting system for improving efficiency of paperworks in international trade transaction processes has been proposed. This system consists of three modules; (1) converting document flows to information flows, (2) reducing information flows, and (3) generating document flows from information flows. Graph theory is adopted to represent international trade transaction processes. Besides, set theory is introduced to describe documents and informations.

To investigate the performances of the proposed system, two experiments are conducted. Two points of view are considered; (1) reducing redundancy of paperworks and (2) flexibility of the proposed system. The first experiment is conducted for validating the proposed system can be applied in an actual situation and confirming the proposed system can be reducing the redundancy of paperworks processes. Document flows and information flows in the trade transaction processes can represent as a common structure by using the mathematical model. Algorithms for reducing redundancy of paperworks processes are proposed by using the mathematical model. As a result, the total number of information transmissions is reduced. The second experiment is conducting for confirming the proposed system. The system can provide a suitable paperworks process for various evaluation criteria.

6.2 Directions for future works

Algorithms for reducing redundancy of paperworks processes are proposed based on reducing redundancy of information flows. From the results of reducing redundancy, redundancy of information flows are eliminated and new document flows are generated. However, synchronizations of procedures and management of access to informations are also important elements in an actual situation. Therefore, theses elements are expected in the future.

Beside, in the proposed mechanism for optimizing paperworks, they have several evaluations in accordance with the requirements of the system designers. The evaluation functions in the second experiment, two types of the redundancy of paperwork processes are used as criteria; (1) redundancy of sharing information and (2) redundancy of using documents. In the experiment, a simple example is shown which have only two sub-evaluation values. However, in actual situations, we have to consider more complex situations that have more compositive requirements and documents. We have to confirm that the proposed mechanism works well in such complex situation in the future. By tackling this problem, LISP processor is considered for implementing the proposed mechanism in the future.

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