

## MASTER

### Managing business process variability

### business process configuration vs. business process customization

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# Managing Business Process Variability

*Business Process Configuration vs. Business Process Customization*

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Master Thesis

**BUSINESS INFORMATION SYSTEMS**

Eindhoven, the Netherlands

August 13, 2013

**Qian Li: *Master Thesis, Managing Business Process Variability*, © August 13, 2013**

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## DECLARATION

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I, Qian Li, declare that this master thesis titled, 'Managing Business Process Variability' and the work presented in it are my own. I confirm that:

- This work was done mainly while in candidature for a master degree at Eindhoven University of Technology.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at Eindhoven University of Technology or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
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*Eindhoven, the Netherlands*

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Qian Li, August 13, 2013



## ABSTRACT

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As the market is becoming more consumer-driven, business is getting more adaptive and customized, which increases the difficulty to build complex and large business processes and manage their variabilities. Keeping business flexible and diverse is the key to improve business performance and attract customers.

**Research Motivation:** Some business processes share similar structures but different variants. It is inefficient to use a standard process for customized business. However, it requires a lot of time and resources to model each process because of a few differences. Configuration and customization are two approaches to manage business process variability. The former approach has been well developed, but it limits the process flexibility. Customization complements this drawback, however, there are limited supports.

Vanderlande Industries (VI) is an international enterprise that designs customized Warehouse Management Systems which compromise a large number of business processes. The systems share many business processes in common but also differ in various ways. VI's design approach is neither internally efficient nor helpful for external communications. VI is looking a solution for managing the commonality and variability of these business processes.

**Objective:** The project aims at investigating a solution for managing the business process variability by applying a case study and evaluating the configuration and customization approaches.

**Approaches:** The project proceeds as follows: 1)conduct a literature review of Business Process Configuration and Business Process Customization and their impacts on organizational practices; 2)select a supporting technological solution; 3)build the configurable process model for VI and extend the tool architecture for customization; 4)collect feedbacks from VI via presentations and surveys, evaluate the approaches against the literature review and give recommendations for enterprises with similar problems.

**Outcomes:** The main results include 1)a state-of-art review and comprehensive evaluations on Business Process Configuration and Business Process Customization, 2)a configurable process model for VI and 3)a proposal of the architecture extension for customization. By comparing two approaches against the literature review and case study, it is concluded that the configuration approach is more efficient than VI's design approach and brings both standards and flexibility. It is time-efficient and seen as a library of references for new designs. However, its limitation of process flexibility makes it unqualified for business. Process customization ensures high business diversity and process flexibility. It is recommended for big organizations to start with Business Process Configuration to save time and cost, and then apply customization to meet customer demands.

Additionally, the directions of future work are pointed out which will improve the configuration and customization approaches, making the propositions more practical for business.



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---

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## ACRONYMS

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ARIS	Architecture of Integrated Information Systems
BPEL	Business Process Execution Language
BPM	Business Process Management
BPMN	Business Process Model and Notation
C-EPC	Configurable EPC
C-EWF	Configurable EWF-nets
C-YAWL	Configurable YAWL
EPC	Event-driven Process Chain
ERP	Enterprise Resource Planning
EWF-Net	Extended Workflow Net
I-Option	Interference Option
IP	Interference Point
IS	Information Systems
IT	Information Technology
MIS	Management Information Systems
PI-Option	Process I-options
SaaS	Software as a Service
SOA	Service-oriented Architecture
UML	Unified Modeling Language
VI	Vanderlande Industries
WFMS	Workflow Management System
WMS	Warehouse Management System
XML	Extensible Markup Language
YAWL	Yet Another Workflow Language



Part I

FOUNDATIONS



## INTRODUCTION

---

With a growing interest in *Business Process Management* (BPM) from the academic circle and industry over the past decades, a great majority of organizations have already built their business process models to some extent, for both internal and external activities.

**Definition 1.** *Business Process Management includes methods, techniques and tools to support the design, enactment, management, and analysis of business processes - W. van der Aalst [33].*

There are many definitions of a business process and here are two of them which come from T. Davenport and W. van der Aalst respectively:

**Definition 2.** *A business process is a set of logically related tasks performed to achieve a defined business outcome that usually occurs across or between organizational activities - T.Davenport [7].*

**Definition 3.** *A business process consists of a number of tasks which need to be carried out and a set of conditions which determine the order of the tasks - W. van der Aalst [34].*

Resources required for each activity, information flow between activities, inputs & outputs and execution constraints are also indispensable when it comes to a business process [34]. A business process model is able to capture all these variations and the interactions in between [34]. This property enables a process model to represent a specific type of a process function and is applicable for all types of business functions, for instance handling a claim at a bank, hiring an employee in a company, manufacturing a car in a factory, etc. With different modeling techniques, organizations and enterprises are able to highlight what they consider the most essential factor(s) in their business processes.

Nowadays business is no longer the playground for sellers. Customer-centric business is running the world. Under the influence of the sharply increasing demands for business flexibility and product diversity as well as higher customer satisfaction, the focus has been gradually shifted to the quality improvement of business processes and optimizing the customer and business partner satisfaction. There has been an expanding demand for BPM tools from business to meet these objectives in the past few years. To well manage the business processes, it is of great significance to emphasize on customer relationships and improve the inter-functional integration of all process variations by using Information Technology (IT) [26]. BPM has been proven to possess a positive effect on the overall business performance, interdepartmental connectedness and esprit de corps [26]. The cor-

responding modeling languages, for example UML<sup>1</sup>, EPC<sup>2</sup>, BPMN<sup>3</sup>, YAWL<sup>4</sup>, and tools such as SAP ERP<sup>5</sup> and ARIS Express<sup>6</sup> are capable of supporting the BPM life cycle, which consists of identification, discovery, diagnosis, planning, design, deployment, execution and control of business processes [35].

### 1.1 PROBLEM STATEMENT

Some business processes share similar structures and patterns but different variants from company to company and customer to customer. This is particularly common in organizations from the same service business or industry field, for example the process of handling a claim can be found in any bank and most companies have a recruitment procedure. Take an example of the order-delivery process:

*Order-delivery processes exist in a large number of companies and have many features in common especially the high-level structure. However, the order-delivery processes differ significantly considering the business type. An order for a physical delivery is quite different from an order of service since there is a discrete deadline for the physical delivery while it is rather flexible and can be adjusted for a service delivery. There are more quality controls for a service delivery than a physical delivery, which also largely changes the business processes.*

*Therefore, it is not practical to have only one order-delivery process if a company sells both physical products and services.*

However, it takes a lot of effort to model every business process because of a few differences even though the processes share many activities in common. For instance, the same type of products for different customers from the same company usually have more in common and so do their processes:

*A warehouse system supplier manufactures automated warehouses for clients and each system consists of receiving, storage, picking, packing and shipping. Despite the different variants such as the conveyor size, the system capacity, the automation percentage and so on, it would still be inefficient to design and model a warehousing system whenever a new client shows up with new requirements.*

The long lead time and high cost of modeling every business process prompted the BPM professionals to seek for a solution for adapting to the business diversity, improving the modeling quality of business processes.

Self-adaptation and customization of business processes are able to help with such situations. The concept of **Business Process Configuration** came forward with a complementary effect for reference process models which enable the reuse of best practices across process design projects [5] but lacks the ability to present all variations and configuration decisions [24].

<sup>1</sup> <http://www.uml.org/>

<sup>2</sup> [http://wiki.sdn.sap.com/wiki/display/ModHandbook/Process+Modeling+-+Event+Driven+Process+Chain+\(EPC\)](http://wiki.sdn.sap.com/wiki/display/ModHandbook/Process+Modeling+-+Event+Driven+Process+Chain+(EPC))

<sup>3</sup> <http://www.bpmn.org/>

<sup>4</sup> <http://www.workflowpatterns.com/yawl/>

<sup>5</sup> <http://www.sap.com/solutions/business-suite/erp/featuresfunctions/index.epx>

<sup>6</sup> <http://www.ariscommunity.com/aris-express>

**Definition 4.** *A configurable process model is a model that contains all variants of a business process for a specific business function and describes all possible combinations of its activities [21].*

It is a pre-defined process model that allows business analysts to configure their desired business processes by assigning different values to the process variations [24]. After completing the configuration settings, process models can be individualized automatically so that the risks of technical modeling errors can be easily avoided. There already exist a few tools that support process configuration, for instance YAWL and EPC. W. van der Aalst and F. Gottschalk developed the language, configurable YAWL (C-YAWL), for configuring business/workflow processes [10]. Despite the fact that Business Process Configuration is able to manage the variability of business processes to some extent within the process family, it still limits the modeling freedom since all configurations have been already defined by the process owners.

Standing from a different angle, another concept was proposed to cope with the business process variability, namely **Business Process Customization** [13]. Customization is a common requirement in business and many companies and organizations are making profits by customizing services and products.

**Definition 5.** *A customizable process model is a collection of multiple process variants or even sub-processes that are applicable or possible for a process type [13].*

By offering various process elements and adjusting points, it allows more freedom for users to change process properties and construct business processes. Process customization consists of a base process representing one business function and a series of change options that can be applied to this process [13]. The change options allow users to add, delete, move the process variants and modify the properties of the process elements.

As increasing the flexibility of process modeling, customizing business processes leads to a high risk of error making and requires a large amount of modeling effort, which makes it a distinct disadvantage for enterprises to practice in business [15]. So far, not many applications have been developed to fully support the customization functions. The development and implementation of Business Process Customization remain to be studied.

#### 1.1.1 A Real Case

*Vanderlande Industries*<sup>7</sup> (VI) is one representative enterprise with such problems. VI is an international company and one of the largest companies that provide goods handling systems with specializations in baggage handling systems, automated warehouses and post & parcel sorting facilities. VI designs and manufactures *Warehouse Management Systems* (WMSs) for distribution centers in four domains, namely food retail, parts and components, fashion and tires.

Each WMS is complex and comprises a large number of business processes. VI provides a unique solution for each customer to satisfy their business demands.

<sup>7</sup> The headquarters of *Vanderlande Industries* is located in Veghel, the Netherlands.

The designs have many processes in common. However, details can vary largely and make a difference to the business processes. Therefore, the WMS designs also differ in various ways. Designing the business processes for each WMS requires a lot of time, resources and cost.

To design and manufacture the physical equipments for a WMS, the business functions within a WMS must be defined in the first place, which is achieved by collecting the customer requirements. Normally, VI collects the customer requirements in texts and draws up the infrastructure layouts based on those. The consequences of converting textual requirements to infrastructure layouts is long design time and a lot of resources and cost, especially when many designs have a number of business processes in common. It is time consuming to convert the business processes from the textual descriptions to the mechanical designs.

When a system designer wants to review the business processes from the existing solutions, it is also difficult to extract the precise information from texts. Furthermore, it increases the difficulty to communicate with VI customers and business partners since they might not have adequate knowledge in this area. Once a change is required from a customer or business partner, it again requires a lot of time and effort to change in texts and layouts.

To improve the working efficiency, business performance as well as the external communications with business partners and customers, VI urgently needs to change its design approach by modeling the business processes in a structured way to manage the diversity of its WMS business processes. However, how to manage the similarities and variabilities of the WMS business processes is more challenge for its business performance, which is significantly essential for VI.

## 1.2 SCOPE & OBJECTIVES

In this thesis, the main objective is to investigate the solution to manage business process commonality and variability with a case study of the VI scenarios. By helping improve the working efficiency and business performance of organizations, the project aims at analyzing Business Process Configuration and Business Process Customization from the literature, validating the approaches against the case study and providing generic suggestions for organizations to manage the business process variability, increase the business flexibility and improve the quality of process modeling. A case study of the WMS business processes from VI is applied to validate and evaluate the configuration approach in the real business environment while on the other hand to study the business needs for process customization and how it can be developed. Specifically, the following questions are to be answered during the research:

1. What are the benefits and drawbacks of Business Process Configuration and its impacts on organizational practices?
2. What are the benefits and drawbacks of Business Process Customization and its impacts on organizational practices?

3. Which are the similarities and differences between Business Process Configuration and Business Process Customization?
4. What are the available technological solutions for Business process configuration and/or Business process customization?
5. How can the configuration and customization approaches be applied to a specific business scenario?

### 1.3 THESIS STRUCTURE

To provide a clear overview, the current thesis proceeds as follows. It consists of three parts, describing the background knowledge, the project outcomes and some extra annotations respectively.

**PART 1: FOUNDATIONS** The first part serves as an introduction to this master project and a foundation for the research.

- [Chapter 2](#) clarifies the methodologies applied during the project, from forming the research topic to the final evaluations.
- [Chapter 3](#) presents the review of the selected academic papers, containing more detailed information about Business Process Configuration and Business Process Customization. It introduces the background for the core research and therefore, is an essential foundation for this master project.

**PART 2: OUTCOMES** This part presents the core of this project, including the tool selection for modeling business processes, the proposed solutions and evolutions.

- [Chapter 4](#) reasons the tool selection for modeling configurable and/or customizable business processes.
- [Chapter 5](#) describes how C-YAWL supports process configuration and the working theory behind it; and illustrates the business needs for process customization, the proposed architecture extension of YAWL in addition with the Customization Service and the examples of process customization in YAWL.
- [Chapter 6](#) analyzes VI feedbacks and compares a configurable and a customizable models based on the VI WMS business processes against the analysis from the literature review.
- [Chapter 7](#) concludes the project with the answers to the research questions proposed in [Section 1.2](#), along with the research limitations and corresponding future work.

**PART 3: APPENDICES** The last part of this thesis contains the citations and extra information which is not presented in the main body.

- [Appendix A](#) supplements all extra figures and tables mentioned in the literature review.

- [Appendix B](#) provides the necessary process models in bigger sizes for a more clear view.
- [Appendix C](#) presents survey template for collecting VI feedbacks.

## METHODOLOGY

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In this chapter, the methodology applied to accomplish the master project is introduced. [Section 2.1](#) provides a background of the major research paradigms in the Information Systems (IS) field while the other sections specifically explain all the approaches chosen in this project.

### 2.1 RESEARCH PARADIGM

There are two paradigms that characterize much of the research in the IS discipline, namely behavioral science paradigm and design science paradigm [16].

#### *Behavioral Science Paradigm*

It seeks to develop and justify theories (i.e. principles and laws) that explain or predict human or organizational phenomena surrounding the analysis, design, implementation, management, and use of IS [16]. Such theories ultimately inform researchers and practitioners of the interactions among people, technology, and organizations that must be managed if an information system is to achieve its stated purpose, namely improving the effectiveness and efficiency of an organization [16]. Data collection and empirical analysis are the core techniques applied to behavioral science research which is originated from natural science research methods.

#### *Design Science Paradigm*

This paradigm seeks to extend the boundaries of human and organizational capabilities by creating new and innovative artifacts [16]. The design-science paradigm has its roots in engineering and the sciences of the artificial [31]. It creates and evaluates IT artifacts intended to solve identified organizational problems, mainly using computational and mathematical methods to evaluate the quality and effectiveness of artifacts. Design science which is fundamentally a problem solving research paradigm originated from the engineering discipline and the sciences of the artificial.

The paradigm applied to this master project is the design science paradigm, for the reason that this research project aimed at evaluating the configuration approach in the business environment and looking for a way to develop the Customization Service in YAWL which involves computational development. The objective was to provide business analysts with more flexibility of process modeling to improve the business efficiency and effectiveness. Based on the research goals, the design science paradigm is the more suitable for this case.

## 2.2 RESEARCH APPROACHES

Among the methodologies based on the principles of the design science paradigm, A. Jenkins illustrates a general research process for Management Information Systems (MIS) in [18], which is suitable for this master project. Like the interactions between the research steps as shown in Figure 1, many steps during this master project were adjusted as the research went on as well as the project objective.

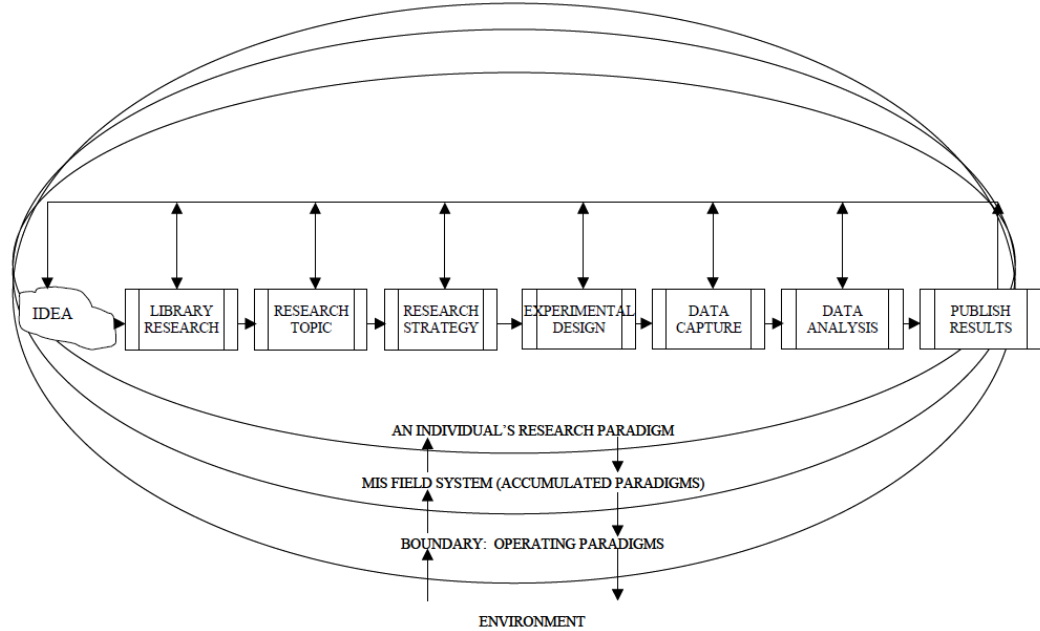


Figure 1: The research process in the MIS field [18]

Combining the research objectives with the principles of this research process for MIS, the approach to conduct this project was determined as shown in Figure 2. Each step answered at least one research question proposed in Section 1.2.



Figure 2: Project approach

### *Literature Review*

New discoveries do not materialize out of nowhere. They build upon previous explorations and findings, and literature reviews have been commonly applied as the foundations of detecting the deficiencies of current knowledge and discovering the unknown world. As a secondary source, a library research, also known as literature review, is a collective study and analysis of the existing research outcomes which are relevant to a specific subject. The Webster & Watson approach [39] provides a well-structured guide to carry out an effective literature review.

Not only does it introduces a framework of writing a literature review, it also teaches how to conduct the search for literature to review. The literature review for the current thesis was performed accordingly, as visualized in Figure 3.

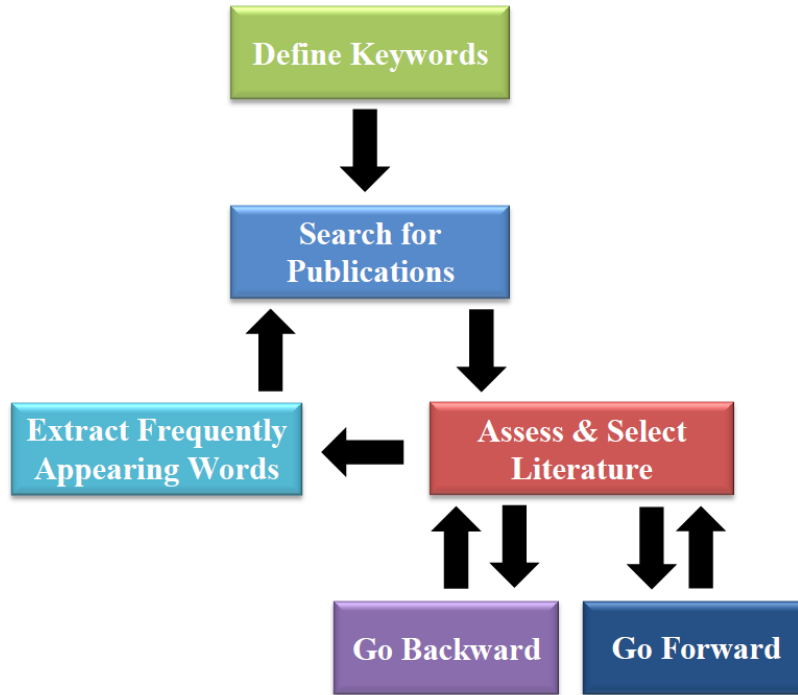


Figure 3: Approach for Literature Review

First of all, to get a comprehensive understanding of the current situations and existing problems at VI, interviews were carried out to collect information and analyze the current situations. After defining the concepts that are relevant to a specific research area, these four steps indicated in [39] were followed to complete a literature review.

#### 1. Step One: identify the relevant literature

Major contributions are likely to be in the leading journals or databases of those famous academic publishers like Springer<sup>1</sup>, ScienceDirect<sup>2</sup>, IEEE Xplore<sup>3</sup>, Google Scholar<sup>4</sup>, WorldWideScience<sup>5</sup>. A hard requirement for the literature search is that all papers must be in English.

Based on the topic determined in the first step, the search for relevant papers started with the keywords of "*Business Process Configuration*" and "*Business Process Customization*" in those mentioned databases and also a reliable BPM forum: BPTrends<sup>6</sup> where some of the citations in this paper come from.

<sup>1</sup> <http://link.springer.com/>

<sup>2</sup> <http://www.sciencedirect.com/>

<sup>3</sup> <http://ieeexplore.ieee.org/Xplore/guesthome.jsp>

<sup>4</sup> <http://scholar.google.nl/>

<sup>5</sup> <http://worldwidescience.org/>

<sup>6</sup> <http://www.bptrends.com/index.cfm>

2. **Step Two: go backward by reviewing the citations for the papers identified in step 1 to determine prior articles to be considered**

The reason is obvious since all new findings are based upon previous investigations. It is helpful to understand how those findings in step one come from and there are chances to discover what has been missing or misunderstood.

3. **Step Three: go forward by using the Web of Science<sup>7</sup> (the electronic version of the Social Sciences Citation Index) to identify articles citing the key articles identified in the previous steps**

This step gave an overview of the latest discoveries and experiments. It could be overlapping with some information from the literature review; nevertheless, it encouraged more advancing thinking.

4. **Step Four: extend the search with most frequently shown keywords**

As the major researchers and papers became clear after these steps, a review of these papers was conducted. The most relevant papers were selected. While reading these papers, words like "*collaborative*", "*adaptive*", "*individualization*" appeared more frequently and they were used as keywords to search in the mentioned databases afterwards.

It was noticed during the review that some topics appear more frequently, for example SaaS. Keyword combinations of "*SaaS*", "*customization*" and "*configuration*" were used for another round of search. Usually an author does not publish only one paper on a topic that he/she has studied. Therefore, a last round of search was performed based on the keywords of the most frequently appearing authors in the selected papers, to check if there was any relevant paper missing. Finally, the essential concepts from the selected literature were used as the foundation of this paper.

As an outcome of the literature review, a deeper understanding of the existing problems was obtained as well as a more comprehensive overview of the available solutions, which are Business Process Configuration and Business Process Customization.

### *Tool Selection*

To apply Business Process Configuration and/or Business Process Customization for the case study, it was essential to choose a proper BPM application. A comparative analysis of relevant tools was conducted. The available technological solutions were compared from different aspects, covering functionality, supporting language, system requirement and familiarity. The choice of YAWL was made in account of the comparative analysis, VI situations and project-relevant factors.

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<sup>7</sup> <http://www.web-of-science.com/>

### *Solution Proposition*

The goal of this step was to build the configurable business process model for VI and extend the architecture of the selected tool to support process customization.

The configurable process model was built in YAWL for VI. The working theory as well as the system architecture of the tool was studied to achieve a deeper understanding of the tool. The configuration options in YAWL was also studied. An example of process configuration in YAWL were provided to explain the C-YAWL working theory.

Due to the limitations of YAWL, the system architecture was extended in addition with the Customization Service. Examples of process customization in YAWL were constructed based on the proposed extended architecture.

The configurable and customization process models were built for VI WMSs, presented in [Chapter 6](#), for evaluations. Because of the information confidentiality, the process models shown in this thesis were modified to protect VI business.

### *Evaluations*

Opinions from VI can provide better insights from different perspectives and are very significant to improve the results.

For evaluations, the solutions were demonstrated to the VI employees and an open session was held to discuss the configuration and customization approaches. After the demonstration, evaluations surveys were sent out to collect feedbacks. The surveys focused on benefits and weakness of each approach and the comparisons between them.

With the approach of Group Feedback Analysis [18], the benefits and drawbacks of configuration and customization became clear. The collected feedbacks of Business Process Configuration and Business Process Customization were comprehensively compared and analyzed with the examples in [Chapter 6](#).

Finally, all the work, including the answers to the research questions, deficiency of the research outcomes and the future work following this research, are concluded in the last chapter.



## LITERATURE REVIEW

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As an outcome of a literature review of the previously described situations in [Chapter 1](#), this chapter collects the essence of the configuration and customization approaches and techniques that have been created or developed to manage the business process variability. With respect to all academic contributions, this review makes a comparison between Business Process Configuration and Business Process Customization from the strategic and operational levels and points out the strengths and drawbacks of each approach as references for modeling business processes.

### 3.1 LITERATURE SELECTION

J. Webster & R. Watson describes a concept-centric method and an author-centric one to structure the review [39]. The concept-centric method was applied in this literature review and a concept matrix was constructed as a start of this review. The key concepts were selected and identified from the citations and [Table 1](#) on the next page shows the relevance between them. The full list of citations can be found in Bibliography while the relevant figures are give in [Appendix A](#).

### 3.2 BUSINESS PROCESS CONFIGURATION

The invention of business reference models set free process engineers from repeatedly modeling the core business functions[5]. As a result of standardization, employees work more efficiently and simply, companies have a unified interface for clients and business partners, learn from best practices and create synergies and information sharing [21]. However, it is frustrating that variable configurations for customer requirements are not allowed, which in another word, there is a risk of losing buyers. One key factor preventing this happening and inefficient reuse of business reference models is the inherent trade-off between standardization and variation [21] and the solution is *Business Process Configuration*. Configuration concentrates on the individualization of a standardized process to fit the needs of an organization. A configurable process model specifies a standard business process and aligns the variation points to this process with various choices executed by different users [11].

Among the selected papers of Business Process Configuration, M. La Rosa et al. [24] provides a very representative and integrated approach to configure multi-

Source	Approaches			Model properties			Objectives		Modeling techniques					
	Configuration	Customization	Comparisons	Soundness checking	Semantics validation	Non-functional requirements	Variability	Maintenance & optimization	Integration & implementation	Web-service technology	EPC	YAWL	Petri-nets	BPMN
[2]		✓			✓				✓	✓		✓		
[3]	✓				✓			✓	✓		✓			
[4]		✓					✓	✓	✓	✓			✓	
[8]	✓		✓	✓			✓				✓			
[10]	✓					✓	✓					✓	✓	
[11]	✓			✓	✓		✓	✓					✓	
[12]		✓				✓	✓	✓						
[14]		✓					✓	✓			✓			
[13]		✓		✓	✓		✓	✓	✓		✓			
[15]					✓			✓						✓
[22]	✓			✓			✓				✓			
[21]	✓				✓		✓							
[23]	✓			✓			✓				✓			
[24]	✓			✓			✓				✓			
[25]	✓	✓	✓			✓								
[27]		✓				✓	✓	✓	✓	✓				
[28]		✓						✓	✓		✓			
[29]	✓		✓		✓	✓	✓							✓
[30]		✓		✓			✓	✓	✓	✓				
[32]	✓	✓	✓	✓	✓			✓	✓		✓			
[38]					✓		✓	✓	✓					
[40]	✓				✓		✓							

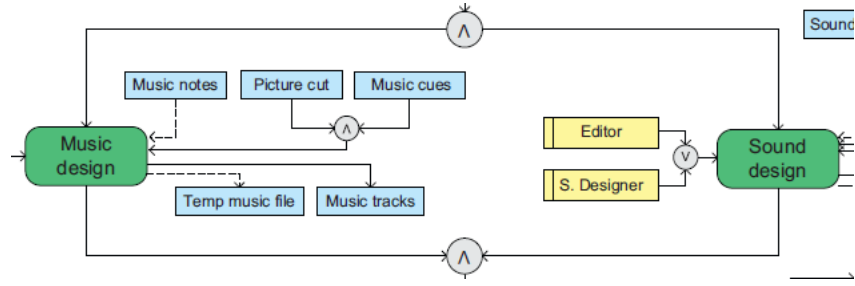
Table 1: Literature review - Concept matrix

perspective business process models. A business process is not merely a task flow, but also contains other important information like resources, constraints, information flow, etc. To fully realize process individualization for organizations, it is obligatory to take all process variations into account. In the approach of M. La Rosa et al., this is conducted by setting configuration parameters defined in the form of simple attributes or logical terms over characteristics.

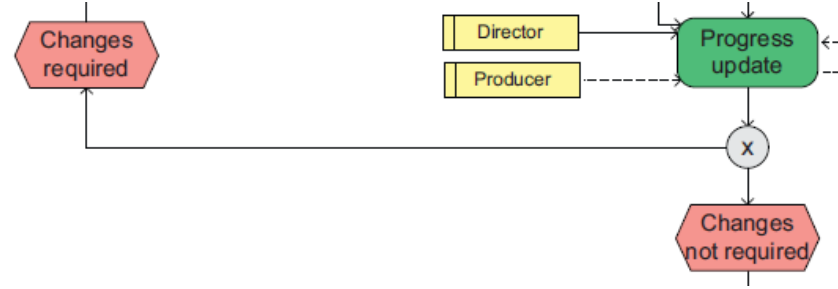
There exist many languages for executable process modeling, among which UML, BPMN and EPC are widely applied in industry. M. La Rosa et al. extended EPCs to C-EPCs as the notations used in his approach, most importantly because the languages allows further development on top of the existing notations. The main elements of C-EPCs are events, functions, control-flow connectors and arcs linking them. In their approach, roles and objects are associated to EPC functions. Objects are on the right side of a function indicating inputs/outputs while roles are on the left where resources are distinguished between human and non-human. Events triggers or conditions, functions correspond to tasks and connectors denote splits and joins of type *OR*, *AND* or *XOR*. Figure 24 shows the main elements in C-EPCs.

To explain how process configuration works, a process instance of audio editing as in Figure 25 is taken by M. La Rosa et al. In the example, roles and objects are linked to functions either directly or via a connector which allows one to specify a logical condition for a set of roles or objects. All variations in the audio editing process have been defined and the process has been modeled so that users can only configure parameters at the variation points. The rules of configurations are illustrated below with screenshots from the process instance.

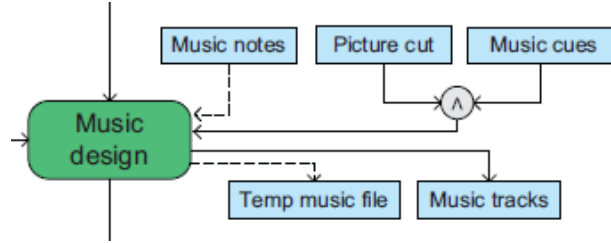
1. Range connectors have two configuration dimensions: *optionality* and *range restriction*. *AND*, *OR* and *XOR* that split or join functions and events are used to configure the route of a business process by turning *ON/OFF* of the functions [24].
  - In Figure 4 rule 1(a), *AND-split* or *AND-join* constraints the process in a way such that both "Music design" and "Sound design" must be in the process.
  - In Figure 4 rule 1(b), *XOR-split* limits the choice after the function "Progress update". Only one of "Changes required" and "Changes not required" can be chosen and must be chosen to proceed.
2. Roles and objects have two dimensions: *optionality* and *specialization* [24].
  - In Figure 4 rule 2, Objects "Music notes" and "Temp music file" are optional, which can exist together or just one or neither.
  - In Figure 4 rule 2, one of "Picture cut" and "Music cues" is mandatory, and only one can exist.
3. The labels of the connectors present the dimensions. The complete set of labels can be found in Figure 26, and here are two examples [24].
  - In Figure 4 rule 3(a), 1:k = at least 1 = *XOR*



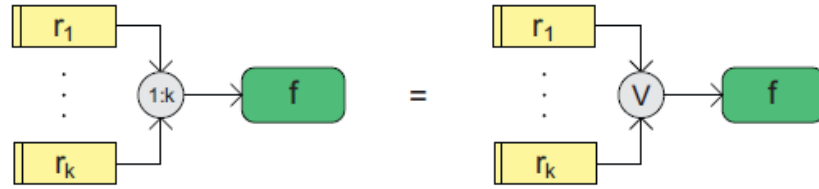
(a) rule 1(a)



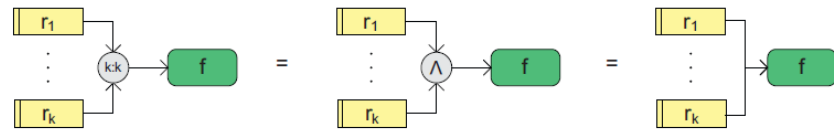
(b) rule 1(b)



(c) rule 2



(d) rule 3(a)



(e) rule 3(b)

Figure 4: Configuration rules in EPC [24]

- In Figure 4 rule 3(b),  $k:k$  (solid line) = all = AND

4. Input objects have one further dimension: *usage* with properties of *consumed* (CNS) and *used* (USE) [24].

- Example: In [Figure 25](#), "Picture cut" is restricted to use if its specialization is "Tape" since a "Picture cut" is only physically destroyed if it is on "Film".

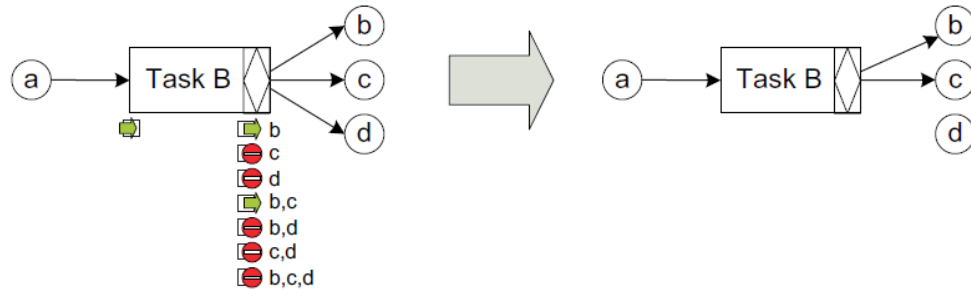
With the approach proposed by M. La Rosa et al., configured process models can be produced. The advantage of this approach is that the process model has been pre-defined and sound, which always leads to sound configured process models. With process checking tools like ProM, it is simple and fast to verify the correctness and soundness of the business process models. Furthermore, M. La Rosa et al. mathematically prove that their approach is syntactically correct and produces the same outcomes as using the configuration approach. What is still missing here is that the semantics behind processes cannot be guaranteed in the configured processes models. Therefore, in the end, semantics checking needs to be done by hand.

Together with other researchers, M. La Rosa has also discussed about the process configuration from other perspectives before publishing this approach, including decision support for configuration [21], configuration for roles and objects [22], linking domains and processes [23] and so on.

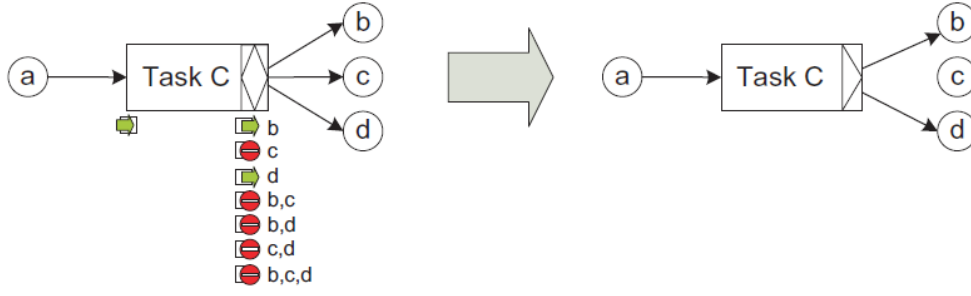
There are many other papers sharing the same principle with the approach from M. La Rosa et al. F. Gottschalk used configurable YAWL (C-YAWL) to model configurable workflow models [10, 11]. YAWL is a modeling language consisting of a set of extended workflow nets (EWF-Nets) and mainly contributed to Workflow Management System (WFMS). C-EWF, namely C-YAWL, has similar notations as C-EPC except that C-EWF clearly shows the input and output of each task (namely function in C-EPC) with notations of *input condition* and *output condition*, see [Figure 27](#). Additionally, C-YAWL contains configuration options for each task like *enabled*, *blocked* and *hidden*. These options differ C-YAWL configuration from C-EPC configuration since in C-YAWL, the configuration is accomplished by changing the properties of a task even though there are also condition choices like *AND*, *OR* and *XOR* while C-EPC can only realize it by using the condition choices. With the configuration options, the C-YAWL models can be transformed into YAWL models, as you can see from the examples in [Figure 5](#). In C-YAWL, the configuration options can be combined based on requirements. Therefore, requirements are essential parts when modeling with C-YAWL. Both approaches from M. La Rosa et al. and F. Gottschalk et al. can be easily implemented with SAP software for industrial use, which gives them an advantage over others.

- [Figure 5](#) rule 6 shows the transformation of an *OR-split* into an *OR-split*.
- [Figure 5](#) rule 7 shows the transformation of an *OR-split* into an *XOR-split*.
- [Figure 5](#) rule 8 shows the transformation of an *OR-split* into an *AND-split*.

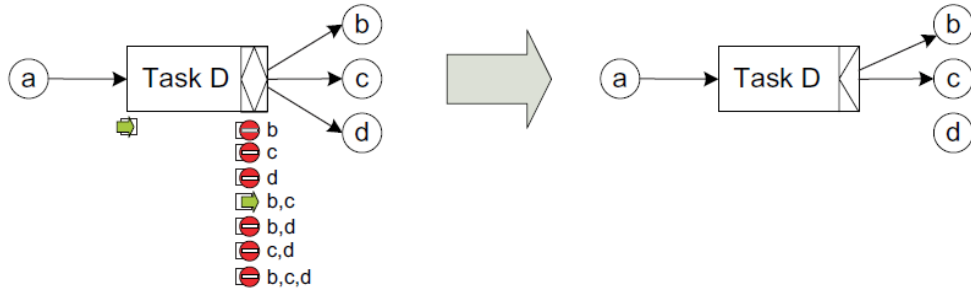
An interesting paper from W. Derguech et al. [8] explains a similar method with M. La Rosa et al. as well, but it also states another three approaches which were abandoned and the reasoning. E. Santos et al. [29] and I. Weber et al. [38] focus on maintaining the behind semantics when configuring business processes. From the



(a) rule 6



(b) rule 7



(c) rule 8

Figure 5: Configuration rules in YAWL [10]

practical point of view, the organizational and operational issues that may occur during configuration are well considered in [40]. Without listing every valuable idea and method for Business Process Configuration, it is learned that this topic has been attracting the business world and remarkable contributions have been made to help enterprises and organizations optimize the efficiency and profits of their business.

### 3.3 BUSINESS PROCESS CUSTOMIZATION

The existence of business variability satisfies the great variety of customer needs [29]. Companies are willing to adjust standards for customers and they are seeking for an efficient and effective approach to cope with business process variability. **Business Process Customization** provides another framework to manage the process variability by using a customizable process model, which is a collection of

multiple process variants or even sub-processes within a business function that enables the customization of a business process by choosing and linking variants [15]. Due to the complexity and uncertainty of business processes in real life, it is still an area under development.

The Provop (PROcess Variants by OPTions) approach [15] contributed a big step forward in the Business Process Customization field. Business processes are defined by a business function which consists of one or more process schemes. In a process schema, variants of the process are included and visualized as a directed graph that comprises a set of nodes like the configurable process models. The BPMN nodes used in the Provop approach are similar with the ones in the configuration approach from M. La Rosa et al., representing activities and control connectors, etc. In addition, control flow edges describe precedence relations between activities, whereas data flow edges correspond to a read or write access of an activity to a data object. Adjustment points show the entry and exit of each node, enabling engineers to restrict the extent to which adaptations may be applied when customizing.

The Provop approach covers the whole process life cycle as shown in Figure 6 and its key principle is to define two sets: process change & process variant and base process & options & process family. A base process is the original process model out of which the different variants can be configured and it can be adjusted to configure a specific process variant [15]. At this moment, the change patterns contain *insert*, *delete*, *move* and *modify*, see Figure 28 for details. A base process is firstly defined in the modeling phase following a set of reusable change operations. Afterwards, it is the configuration phase where the process family is figured out by adding the optional variants to the base process and then one model in the family is executed and transformed into an executable workflow model. Finally, a process family evolves over time and triggers the optimization phase.

A. Hallerbach et al. specifically state the policies for defining the base process and adjustment points and Provop enables all policies. Sequentially, the guidance for designing options for the process family is explained.

- Base Process Policies [15]:
  1. Use a standard process which has been configured to meet specific requirements.
  2. Use the most frequently used process variant(s) to reduce configuration effort.
  3. Apply the minimal average distance between a base process and variant models.
  4. Find the superset of all process variants.
  5. Apply intersection of all process variants: the base process will only comprise those elements that are part of all known process variants.
- Adjustment Point Policies [15]:
  1. Use explicit specification of adjustment points.

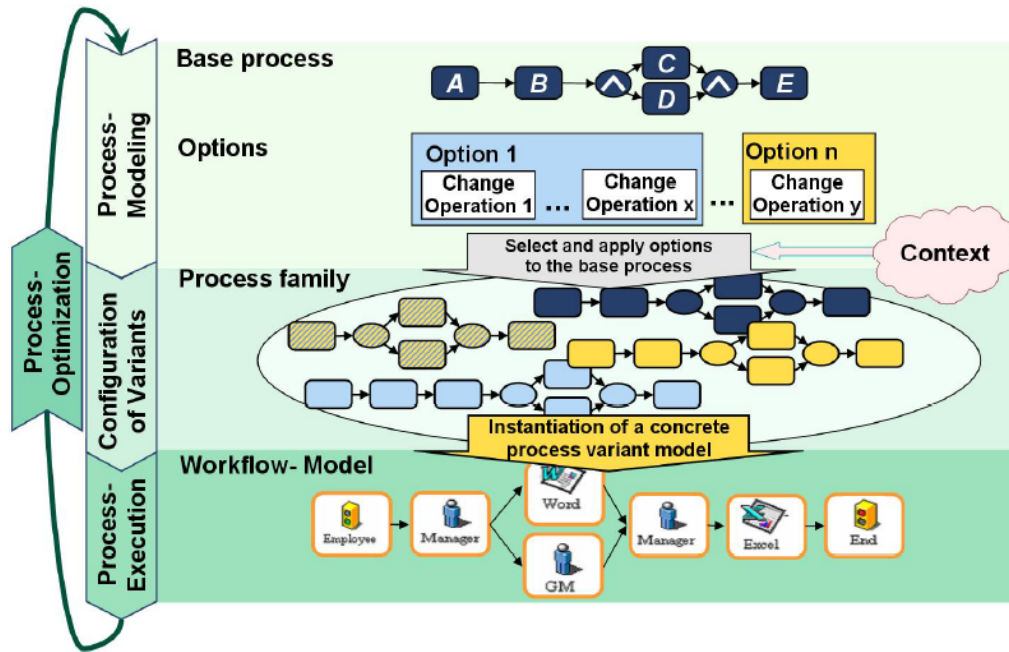


Figure 6: The Provop process variant lifecycle [15]

2. Recommend to use business-relevant reference positions within the base process.
- Process Family Guidance [15]:
  1. Avoid redundant definitions of change operations: changes operations should be grouped into one option if they are always used together.
  2. Use the five option constraints as in Figure 29, namely *implication*, *mutual exclusion*, *application order*, *hierarchy* and *at-most-N-out-Of-M-options*, to avoid semantic errors.
  3. Use the Provop correctness checking framework, see Figure 30.

The Provop checks for the soundness of the customized process models and automatically detect possible source of errors during checks. It also exterminates potential problems related to the evolution of the base process. The clear visions of process variables and the constraints embedded within options reduce the mental effort required by the reader for understanding the processes [32]. There was an implementation of the Provop prototype in ARIS, Figure 31, to realize process customization from this approach. To achieve the implementation of the Provop prototype, A. Hallerbach et al. worked on the details like tool development [12, 13, 28]. Since the framework has not been applied in practice yet, it is not possible to evaluate its performance at this moment. The Provop approach shows a high degree of flexibility for users which will help companies win more customers and business reputations. Still, this superiority does not cover the issues appeared during research. The evolution of the process family, the risk of unsound or incorrect customized process models and the large amount of effort

and time required are crucial challenges on the road to a bright future of process customization.

Another promising approach comes from S. Angelov et al., enhancing the visibility of collaboration between customers and service providers [2]. S. Angelov et al. focus more on the cross-organizational process control and introduces a concept of *Visibility Point* which allows customers to interfere the conceptual process (namely base process in Provop) from the external level with interference points (IPs). There are defined interference options (I-options), i.e. *start* and *pause* at the external level as in Figure 32 and Figure 33. These I-options allow a wide scope of process customization at the external level controlled by customers, i.e. changing time properties, adding or removing tasks, etc. By defining various combinations of IPs, the process I-options (PI-options) enable customers to control the process execution [2]. The difference from the Provop approach is that a process with variant options is provided instead of just process variants. S. Angelov et al. also implemented the prototype based on business process web services as the PROXE (PROcesses in cross-organizational environments) system, which is integrated with YAWL to realize the customization of workflow processes, see Figure 34 for the high-level architecture of his approach and Figure 35 for the implementation architecture.

From a different angle, A. Lapouchnian et al. create a configurable goal model which describes the business processes based on process goals [25]. The end states of goal models are the objectives an organization can reach from a business process, for instance cost, customer satisfaction, internal performance, etc. From configured goal models, organizations will have a clear view of what they can achieve in the end and enable them to adjust the business processes for better business outcomes. On the other hand, J. Becker et al. use a reference-model-based method for a conceptual framework which adapts and integrates reference models to a configured process model [3]. He approaches the adaption from three dimensions, namely layer (*Model*, *Meta*, *Meta-model*), configuration mechanism (*Model type selection*, *Element type selection*, *Representation variation*) and generic reference model adaptation mechanism (*Aggregation*, *Instantiation*, *Specialization*, *Conclusion by analogy*) [2].

Not only in BPM area, in fields like Software as a Service (SaaS), customization of deploying software applies the same principle. A prototype that binds open variation points during deployment of services in the provisioning infrastructure and annotates the explicit variability model with deployment information that the infrastructure can derive [27] successfully demonstrated a customization for SaaS. Moreover, a customization framework that is independent of BPEL engine and web services enables users to customize service and process and handle problems even at runtime of the process [30]. To maintain the customized business processes, monitoring methods have also been developed. Also by using web service, M. Comuzzi introduces a multi-dimensional framework of monitoring patterns to keep track of customer activities and reduce the risk of customization disaster [4].

### 3.4 EVALUATIONS & COMPARISONS

With the knowledge from the previous sections, this section evaluates and compares the two approaches both operationally and strategically.

#### *Business Process Configuration*

Concluding from the previous introduction, process configuration maintains the process standardization which enables organizations to improve modeling efficiency and effectiveness [3, 10, 21, 24] and at the same time increases the flexibility of business processes [10, 11]. On the other hand, all citations on this topic indicate that the variability of a business process is highlighted through configuration which increases the business flexibility, which is a key factor to higher customer satisfaction. By configuring the process variants, organizations can provide more choices than business reference models for customers. From the operational point of view, configurable process models save modeling effort and cost [24], and the risk of error making is sharply reduced once the process model has been correctly constructed [8]. It makes it convenient for organizations to manage and maintain their business processes [3, 32].

When applying a configuration approach, there are a few operational concerns. Firstly, it takes effort and skills to model the configurable model [8, 11]. The configurable model should contain all process variants including potential ones and ensure the soundness of all configured models. The second issue is how to maintain the semantics behind the configured processes. One proposal is to define strict constraints within the configurable process model by analyzing (non-)functional requirements and their relationships [25]. This requires a large amount of business analysis and it is hard to consider all possibilities. Furthermore, the choices of configured models are limited since customers are only allowed to choose from predefined process variants [32]. The options or routes are already defined by organizations and customers can only choose from these fixed options. When time comes that configurable process models no longer fulfill customer demands, changes must take place, in which case that more variations must be added/improved or even the process needs to be adjusted. Adding variants is challenging considering the technical integration and industrial construction while changing processes brings even more problems, like software implementation, legacy systems, etc. [3, 32])

Strategically speaking, however, configuration does not provide customers with much freedom. Flexibility is highly constrained by organizations when they are configuring the process models. In another word, organizations have more control over business processes. Having the overview of the configurable process, organizations can easily see which benefits can be gained. The goal model from A. Lapouchnian et al. can help organizations easily judge whether a configured process is profitable or customer-beneficial [25]. Therefore, organizations with limited capabilities will prefer Business Process Configuration approaches which have both operational and strategic advantages. However, Business Process Con-

figuration is not a long-term strategy since it is potentially limiting (might be even sabotaging) the future business.

### *Business Process Customization*

The examples of successful implementations of SaaS-related customization [30] reflect a promising future of Business Process Customization. The approaches of Business Process Customization allow a large extent of modeling flexibility from the academic perspective [15] and are capable of meeting the increasing and various demands from the market. Organizations can get to know the market changes and business trends by analyzing the customized process models. Customization can certainly bring in more business opportunities and profits for organizations. The strategic strengths are attracting more and more businessmen.

Despite the strategic attractions, the operational skills and techniques are far from qualified to support process customization in real business. The freedom of modeling could result in unexpected customized models. It increases the risks of error making and process family evolving [13, 15], not even mentioning the requirements of modeling effort, time and cost [32]. The integration of variants and changes requires more advanced techniques. At this moment, it is still a topic under development. By handing over the control to customers, process monitoring becomes more significant for organizations [4], especially on the soundness and semantics of business processes. Monitoring methods for process customization like the one in [4] keeps track of customer activities and reduce the risk of customization disaster.

It is significantly challenging to overcome the obstacles for realizing a fully customization of business processes. However, the fast developing technology brings hope.

### *Comparisons*

Summarizing from the previous evaluations, Table 2 on the next page shows the strengths and weaknesses, comparing Business Process Configuration and Business Process Customization.

Simply, an organization models a configurable business process for a business function which contains all allowed variants, choices for process routes and constraints and when there is a customer request, a business analyst configures the model by only choosing from the given choices at certain option points based on specific customer requirements, and that is *delete* process variants from a configurable process model. This is how Business Process configuration works. On the contrary, Business Process Customization tells a story that an organization models a base process like a reference process model which fits a specific business function and separately provides all possible variants including resources, change options and so on, so that a customer can pick any variant and *insert*, *delete* or *move* on top of the base process where adjustment points are located. The advantage of these change operations and separate variables enables customers

		ADVANTAGES	DRAWBACKS
CONFIGURATION	O	Little design effort with a configurable model	Challenge of modeling the configurable process
		Manageable maintenance and supports	Limited variant options
		Low risks of operational errors of implementation and integration	Difficult to add variants after implementation
	S	Cost effective and control at business side	Low business diversity and customer attraction
CUSTOMIZATION	O	Visibility of the business process variability	Huge design effort
		High flexibility of the business processes	High cost and lead time
			Constant monitoring and supports High risks of operational errors Legacy systems issues during the process family evolution
	S	High business diversity and customer satisfaction	Little control at the business side

*O=Operational, S=Strategic*

Table 2: Comparison table of Business Process Configuration & Business Process Customization

to have a clear overview of the process and reduces the semantics mistakes, while organizations must validate the semantics after process customization.

Looking from process modeling perspective, Business Process Configuration and Business Process Customization share the common modeling techniques and requirements. For both approaches, the soundness and semantics of final process models need extra attentions. Without a correct process model, either will improve the business performance or satisfy customer demands. On the other hand, there is no constraint of modeling language since EPC, BPMN, YAWL have all been seen previously. Both approaches have operational challenges although from different perspectives and further development is required.

It is clear to see that configuration is an organization-oriented approach while customization stays more customer-oriented. For organizations, it is less risky to go with process configuration approaches considering being cost and time efficient. The downside for organizations is the limit of business flexibility even though it

is higher than using business reference models. As a consequence, customers will gradually go away. Customization can fill this gap for the reason that it supports very high flexibility of business processes. By giving the control to customers, it helps build the trust and relationships with customers, which has a direct effect on customer satisfaction. However, one cannot make an omelet without breaking eggs. The difficulty of customization lies in the operational aspect for organizations. How to spend less time and fewer resources but at the same time guarantee the quality of business processes is the question that needs to be answered. To conclude Business Process Configuration is more practical and efficient for organizations but with a lower strategic score, while Business Process Customization wins from strategic aspect but far lagging behind on the operational level.

### 3.5 REVIEW CONCLUSIONS

Business Process Configuration and Business Process Customization both make business processes more flexible and these two topics are getting popular among business. The biggest challenge is to develop more advanced techniques to optimize the degree of customization. Furthermore, the customization approaches need to be tested in real life business to check the actual performance and receive user feedback. How to make a choice between configuration and customization for organizations is not as easy as it seems to be. It requires considerate evaluations of the strategic and operational capabilities of the organizations and comprehensive Risk Management.

From the academic point of view, Business Process Customization can be seen as an evolution of Business Process Configuration despite the owner of control. Both approaches require certain variant points to realize the configuration/customization. The next step is to search for a solution to easily integrate variant options with (base) processes and define a more concrete method to design the base model. For organizations, the real question is "*Do we have the capability and resources for process customization?*" Considering unexpected variance of business processes and higher customer expectations, how to efficiently model a customizable base process and capture all options for a business function is a challenge, and it requires more comprehensive market investigation and business analysis. A possible solution for organizations to take advantage of all strengths is to let a customer customize a desiring process model and at the same time configure the process internally. Afterwards, the configured process is compared with the customized one to find out the differences. With modifying and negotiating, a final process model could consist of parts from the two process models to satisfy both parties.



## Part II

## OUTCOMES



## TOOL SELECTION

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By answering the research question "*What are the existing technological solutions to provide configuration and/or customization process models?*", this chapter mainly discusses about the available supporting applications and the tool selection to support the management of business process variability, considering both the configuration and customization perspectives.

### 4.1 TOOL FOR CONFIGURATION

A software application must be chosen to model a configurable process model. There are many software applications developed for process configuration and **Synergia**<sup>1</sup> is a toolset which comprises six interrelated tools to provide end-to-end support for process model configuration [20], including Questionnaire Designer, Quaestio, C-EPC Designer & Process Merger, C-YAWL Editor, C-Mapper, Process Configurator and Process Individualizer. This toolset provides very comprehensive support for configurable process models, however, VI does not need as many functionalities as Synergia offers. The purpose of VI is to be able to visualize their WMS business processes for customers and offer a platform to easily discuss and modify the processes. To select the suitable element from Synergia, let's first look at what can be supported by each of these tools.

- *Questionnaire Designer*<sup>2</sup> enables modelers to visually create questionnaire models which can be later imported into *Quaestio* and helps spot undesired circular dependencies among facts or questions [20].

It is able to show the variant choices in a decision-tree model and the dependencies; and it is a better way than textual descriptions which do not clearly show the connections between business processes. However, Questionnaire Designer does not visualize the workflow of a process model, which might be incontinent for enterprises.

- *Quaestio*<sup>3</sup> is a questionnaire tool which can be used by domain experts to configure the features of a given domain. It collects the requirements for a configurable process model by asking questions [20].

<sup>1</sup> <http://www.processconfiguration.com/tools.html>

<sup>2</sup> <http://www.smartsurvey.co.uk/questionnaire-design/>

<sup>3</sup> [http://www.cope.nl/producten/quaestio\\_survey\\_manager](http://www.cope.nl/producten/quaestio_survey_manager)

This tool can be used to collect customer requirements, which has nothing related to present the business processes. Therefore, it is not an option.

- *C-EPC Designer & Process Merger*<sup>4</sup>: C-EPC Designer is a visual designer for EPC, C-EPC and C-iEPC process models and Process Merger is used to merge (C-)EPC process models into one C-EPC process model [20].

These two tools are able to help organizations with the design problem. EPC has been widely used in industry as well and many applications can support this language. It is regarded as one choice for modeling configurable process models.

- *C-YAWL Editor*<sup>5</sup> caters for the creation and configuration of C-YAWL models. It allows to configure the inflow and outflow ports of tasks, cancelation region and multiple instance parameters [20].

This is another tool that suits the case study.

- *C-Mapper*<sup>6</sup> allows users to define c-mappings between questionnaire models and configurable process models defined in C-EPC or C-YAWL [20].

It has nothing related to the project objective, so can be ignored.

- *Process Configurator*<sup>7</sup> configures a process model according to the answers of a questionnaire [20].

It is a tool related to *Quaestio* and since *Quaestio* is not considered helpful, Process Configurator is not a good option.

- *Process Individualizer*<sup>8</sup> transforms each configured variation point to the variant it has been assigned to, and removes those process fragments that are no longer required to generate an individualized process model from a (partially) configured process model [20].

This tool can be used together with C-EPC Designer or C-YAWL Editor to present the final configured process models.

From the first step analysis of what each tool is capable of, the scope was narrowed down to *C-EPC Designer*, *C-YAWL Editor* and *Process Individualizer* (if necessary). To achieve a final decision, a second step analysis of *C-EPC Designer* and *C-YAWL Editor* was conducted, see Table 3.

#### 4.1.1 Selection Analysis

Besides the comparisons from the academic point of view, the situations in the case study are also important for the tool selection. The VI system designers are

<sup>4</sup> <http://www.processconfiguration.com/tools.html>

<sup>5</sup> <http://www.yawlfoundation.org/>

<sup>6</sup> <http://www.processconfiguration.com/tools.html>

<sup>7</sup> <http://www.processconfiguration.com/tools.html>

<sup>8</sup> <http://www.processconfiguration.com/tools.html>

	C-EPC DESIGNER	C-YAWL EDITOR
Functionality	As an <b>Eclipse</b> plug-in, it captures resources and business objects [20].	C-YAWL is one service in YAWL and able to preview the configured process. It also checks the correctness of any induced individualization given a configuration [20].
Modeling Language	EPC is a type of flowchart and contains events, functions and logical connectors.	YAWL is based on Petri-nets and more advanced. It contains conditions and tasks.
System Requirement	Eclipse v.3.4 or above; GEF v.3.4 or above; platform independent; <b>Java Runtime Environment 6</b> or above	Java Runtime Environment 6 or above
Cost	Open-source, released under the <b>GPL</b> v3 licence.	Open-source, released under the <b>LGPL</b> v3 licence.
Familiarity	Familiar with the EPC language, but not much practical experience	Often used in project, have the operational knowledge

Table 3: C-EPC Designer vs. C-YAWL Editor

not all BPM experts and most of them do not have extensive IT knowledge. Therefore, an application that is straightforward to understand and easy to operate is better for their working efficiency.

Given the situations, YAWL was the ideal choice for this project and therefore chosen to build the configurable process model with the following reasons:

- **Language Simplicity:** Both EPC and YAWL languages are easy to understand, but from the simplicity perspective, YAWL is better since the split and join are shown in tasks instead of using connectors separately. Logical connectors might cause confusions for customers as well.
- **Few IT Requirements:** As a plug-in in Eclipse, *C-EPC Designer* requires more platforms and supporting environments to function, while YAWL only needs Java Runtime Environment. Using YAWL is easier for users to avoid IT issues.
- **Functionality Diversity:** Most importantly, C-YAWL feature is only one feature of the YAWL application and YAWL is capable of complex workflow management and more advanced integration with other services.
- **Application Independence:** YAWL is also capable of showing the configured process models without the help of Process Individualizer, which is also convenient for the VI system designers.

- **Cost-effective:** The cost aspect did not affect the decision much for the reason that both applications are open-source for educational purposes. Being cost effective is a strategic benefit for enterprises.
- **Tool Familiarity:** EPC is used in very powerful process modeling tools, however, there have been not many practices during the study compared to YAWL. From the familiarity point of view, using YAWL is able to avoid some operational difficulties.

## 4.2 SYSTEM ARCHITECTURE OF SELECTED TOOL

*Yet Another Workflow Language* (YAWL) is a language based on Petri-nets, Workflow Patterns and a well-established concurrency theory with a graphical representation [1]. The YAWL application is a BPM/Workflow system to handle complex data transformations and full integration with organizational resources and external Web Services. It offers many distinctive functionalities [1], among which is the configuration of the YAWL process models.

YAWL System is structured as a service-oriented architecture (SOA) and it is composed of an extensible set of YAWL Services, each of which is deployed at a certain endpoint and offers one or multiple interfaces [36]. There are three layers in the YAWL system architecture, namely the presentation layer, business logic layer and the data layer, see Figure 7. YAWL System offers very extensive features such as support for control-flow patterns, etc. Not all of the system components are relevant to process configuration, therefore, only the relevant ones are introduced here.

**Inner Layer:** The execution data and workflow specifications are stored here, which covers three aspects: the control-flow logic, the data definitions (XML schemas, input and output mappings for each task, and boolean conditions for conditional flows) and the resources required to execute the various tasks [36].

- *Process models:* work specifications of process models in XML schemas
- *Organizational model:* a model that specifies resources and information about the participants, such as roles, capabilities
- *Execution data:* case data and execution logs, which are individual case data and event representations, e.g. start time, end time
- *Codelets:* repository of code snippets that are executed internally by *Workflow Engine*
- *Worklets:* repository of small YAWL workflow specifications designed to execute as a substitute for an enabled work item

**Business Logic Layer:** The core service of YAWL System is *Workflow Engine* in the business logic layer and it is responsible for creating, routing, and synchronizing the execution of work items according to a workflow specification [36]. Developers are allowed to extend YAWL System and introduce custom services that interact with the engine or with the task-related YAWL services.

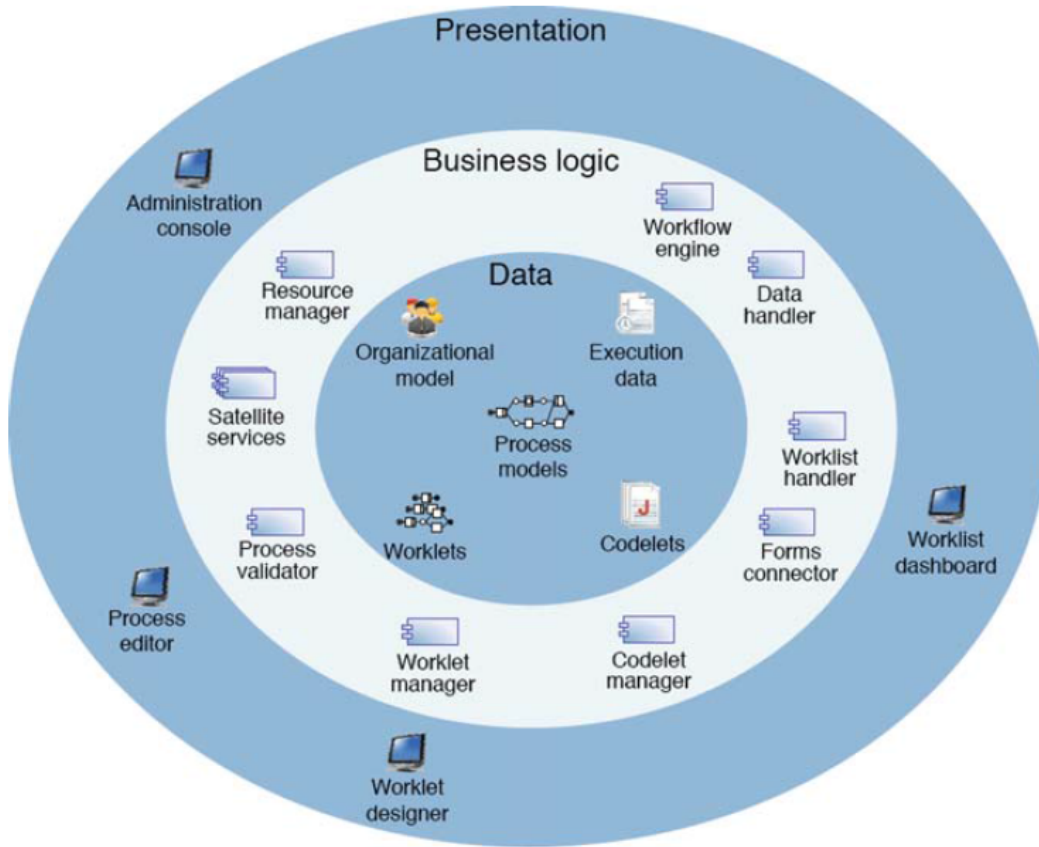


Figure 7: YAWL system architecture [36]

- *Process Validator*: handle the validation of the workflow specifications, both syntactically and semantically
- *Data Handler*: manage and exchange data within the *Workflow Engine* for different services
- *Resource Manager*: manage the allocation of resources to work items. A work item is a runtime instantiation of a task defined in a workflow specification together with its associated data, and is instantiated from its task definition when controlflow reaches the task during execution of the process instance [36].
- *Codelet Manager*: handle automated work items and delegates the execution of codelets
- *Worklet Manager*: submit the completed form to *Workflow Engine* any data gathered during the execution of the work item
- *Worklist Handler*: offer and allocate manual work items to users and transfer the associated business data through a Web form
- *Forms Connector*: combined *Worklist Handler* to allow the connection of manual work items to custom-made Web forms

**Presentation Layer:** This layer provides interfaces to users to create workflow processes and execute work items.

- *Worklist Dashboard*: interfaces shown during an execution of a workflow process, which enable users to query the set of work items being offered to them, allocate a specific work item to themselves (thus locking it), start a work item, or complete it
- *Process Editor*: allow users to create and edit workflow specifications
- *Worklet Designer*: the design interface of the worklet service
- *Administration Console*: administration interface to change identifications and permit access control

The definition of configurable YAWL models is supported in *Process Editor*, same as *YAWL Editor*, without affecting the other YAWL services. Figure 8 shows that the workflow specifications are stored in XML schemas and then passed to the runtime environment through *Workflow Engine* to interact with the other YAWL services. *Process Editor* uses layout information in conjunction with the conceptual information to represent a workflow [36]. The functions in *Process Editor* allow users to make a task configurable and choose different settings in order to obtain a configured process model. These functions make changes to the XML schemas of the workflow specifications in the background and reflect the configured process model in *Process Editor* after changes.

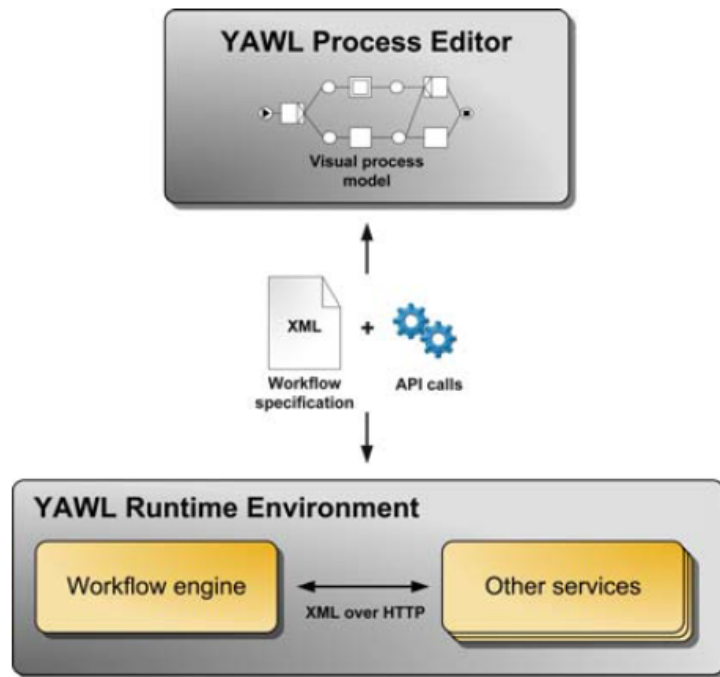


Figure 8: Design and runtime environment interaction [36]

Inspired by the definitions in the Workflow Reference Model [17], *YAWL Engine* interacts with its services in the through four interfaces. With the specifications

from the YAWL developers [36], the core services and interfaces, Figure 9, are described as below.

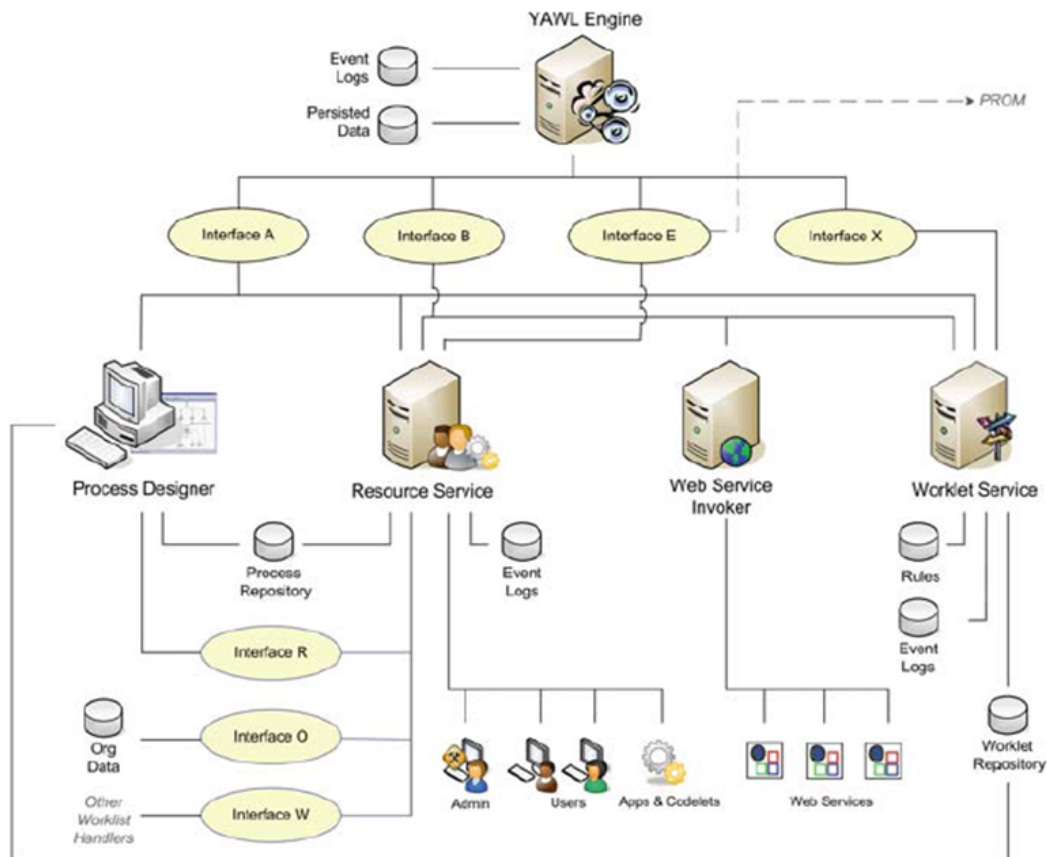


Figure 9: YAWL core services and interfaces [36]

- *Interface A* provides endpoints for uploading and unloading process specifications, registering or removing references to external services and basic user connections and disconnections.
- *Interface R* provides access to the organizational data by authorized external clients (such as, but not limited to, the *Process Designer*). This interface provides sets of both human resource and codelet descriptors.
- *Process Designer*, which is *YAWL Editor*, provides the user interface for the creation and verification of YAWL process specifications.  
Through *Interface A*, it obtains a list of services to associate with a task. It provides design tools, routing constructs and soundness check.
- *Process Repository* stores the XML schemas of the work specifications of the process models developed in the *Process Designer*.
- *Resource Service* allocates enabled work items to resources so that they can be processed.
- *Interface O* provides an interface to organizational data sources.

- *Interface W* exposes the entire worklist routing functionality to allow external, specialized worklists to be developed and implemented.
- *Interface B* provides endpoints for services to establish a session with the Engine, launch process instances, check work items in and out of the Engine, and retrieve process data and state information.
- *Interface E* provides endpoints for the retrieval and analysis of process logs.
- *Interface X* provides endpoints for the detection and handling of runtime process-level exceptions.
- *Worklet Service* enables dynamic flexibility for process instances and provides facilities to handle both expected and unexpected process exceptions at runtime.
- *Web Service Invoker Service* provides a mediation layer between YAWL Engine and external web services to route the automated work items to SOAP web services.

#### 4.3 TOOL FOR CUSTOMIZATION

So far, there have been very few BPM tools in the market developed for Business Process Customization. A capable application is AristaFlow BPM Suite<sup>9</sup>, which enables users to define customized change options first and choose to apply them to specific positions in a process template, which is called "*plug & play*" [6]. The defined change options are stored in a separate repository from the one for the process templates.

AristaFlow BPM Suite provides extensive services to manage business processes and easy integration of applications and services. It is free of charge for research and education purposes [9], meaning companies might need to pay for the software licence. This is a negative factor when companies are selecting a tool for business.

As introduced previously, YAWL is able to support Business Process Configuration. However, it has not implemented the Customization Service yet. The current system does not provide the functionality to define a change option and apply it to a process model in YAWL Editor. Process customization is different from manually linking process variants when designing a process model in YAWL Editor.

Even though configuration and customization are two different approaches to manage process variants, the principle is similar that they both make changes to the process variants in a process model. The previous chapter together with [Section 5.1](#) explain how configuration is supported in YAWL. In short, YAWL realizes process configuration by changing specific values in the XML schemas. Inspired by the way configuration is realized in YAWL and how AristaFlow BPM Suite realizes process customization, it is also possible to develop customization functions in YAWL, by defining the change options in XML and making changes

<sup>9</sup> <http://www.aristaflow.com/home.html>

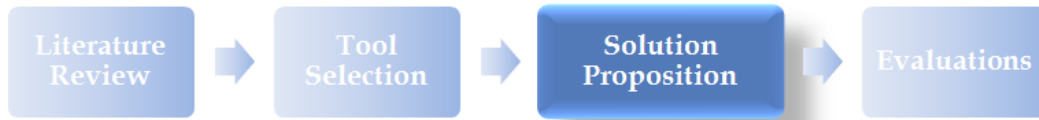
to the XML schemas of the process model to automatically trigger customizations in YAWL Editor.

Additionally, YAWL is supported by an open source environment developed in part in collaboration with industry. It can be extended with customized services and handles complex data transformations, and full integration with organizational resources and external Web Services [34], enabling companies to extend the application to adapt to their business needs.

Considering the situations of this project and familiarity of the tools, YAWL was selected and its potential to support Business Process Customization was analyzed. With the knowledge of C-YAWL, the Customization Service can be developed. It is also superior to have one application that supports both Business Process Configuration and Business Process Customization for cost saving and working convenience when enterprises are considering to purchase a BPM application. Furthermore, the diversity of YAWL supports more than process configuration for an enterprise, which provides another attraction for companies to further benefit from the other features of YAWL.



## SOLUTION PROPOSITION



This chapter specifies the proposed solutions with a wrap-up theory from the literature review. A specific solution to the case study is also demonstrated, consisting of a configurable and a customizable process models of the warehouse business processes.

### 5.1 BUSINESS PROCESS CONFIGURATION

#### 5.1.1 Concept & Theory

As an approach to manage the variability of business processes, Business Process Configuration handles business processes that are similar to one another in various ways and differ in some other ways from one organization or business functions to another. These business processes belong to a process family. It relates to the lifecycle of configurable process models, from their design to their configuration and individualization [19], to fit the needs of an organization, such as locating the business processes to different countries, satisfying different customer requirements, etc.

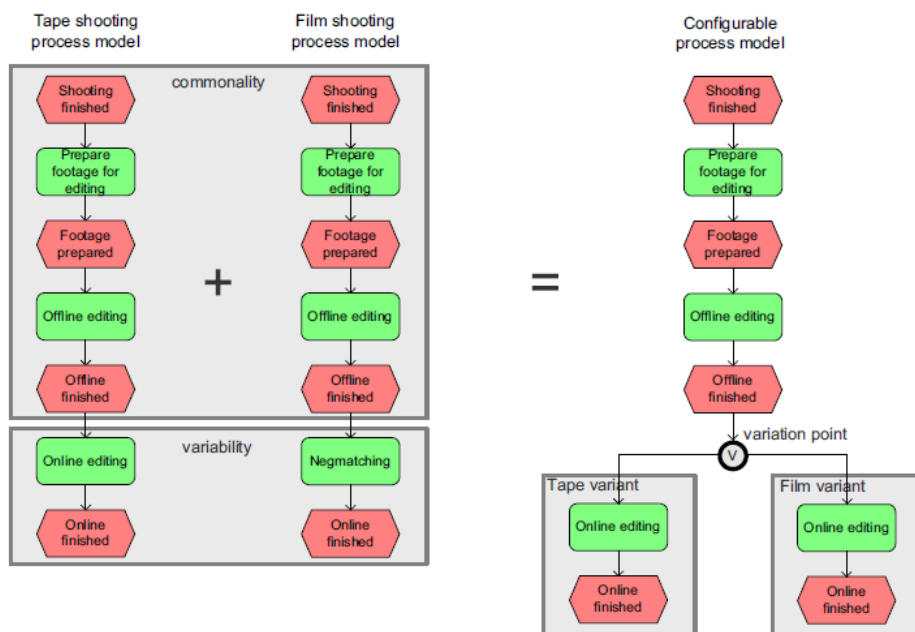


Figure 10: Forming a variation point [24]

A configurable process model specifies a standardized business process and aligns the variation points to this process with various choices executed by different users [11]. A variant point can be specified in different ways, each representing a business decision. Here is an example of merging commonality and variability of two business processes into one by using a variation point in Figure 10. It is an integrated representation of multiple variants of a same business process in a given domain, such as the order-delivery business process in Section 1.1; and the core feature is the explicit representation of variant points and their variants [19].

Compared with traditional process models, a configurable process model eliminates the redundancies in a process family and fosters standardization and reuse of proven practices [21]. It has a complementary effect for reference process models which enables the reuse of best practices across process design projects [5] but lacks the ability to present all variations and configuration decisions [24]. Business Process Configuration enables a clear distinction between commonalities and variabilities in a process family. Process designers can use different configurations to meet specific requirements, resulting in different business process models. Different from the traditional BPM lifecycle, the design phase is split into two phases: one where the configurable process model is designed from the consolidation of selected process variants, and another where the model is actually configured and individualized to fit a particular setting, as shown in Figure 11.

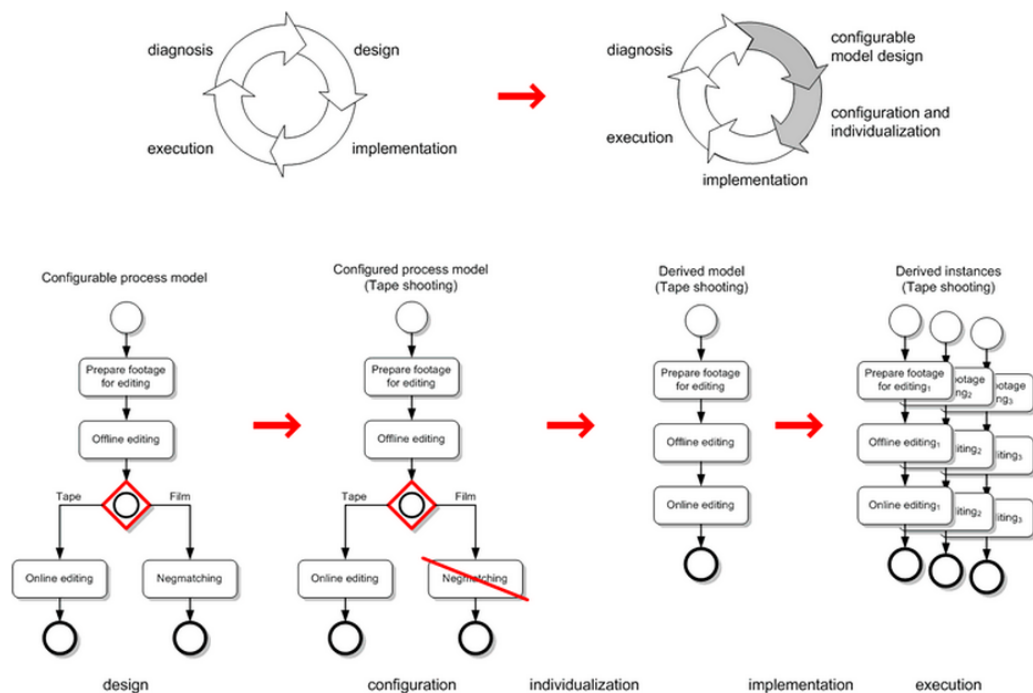


Figure 11: Configurable process model lifecycle [19]

### 5.1.2 Configuration in YAWL

The configurable tasks are distinguished by a thicker border from the remaining tasks representing commonalities [1]. Any task can be set configurable by the following steps: right click on the task → *Process Configuration* → click on *Set Task*

*Configurable* [1]. A task can be set as *activated*, *blocked* or *hidden* from the *Input Ports* of the task itself. Configuring the *Output Ports* will have an effect on the next task or all the following tasks. Once a task is blocked, all the tasks following the blocked one are as well blocked. Whilst, the following tasks of a hidden task will not be affected. YAWL is also able to show the final process model after configuration.

To explain the configuration options of a task, let's first take a look at the ports of a YAWL task with more than 1 incoming/outgoing process branch in Figure 12.

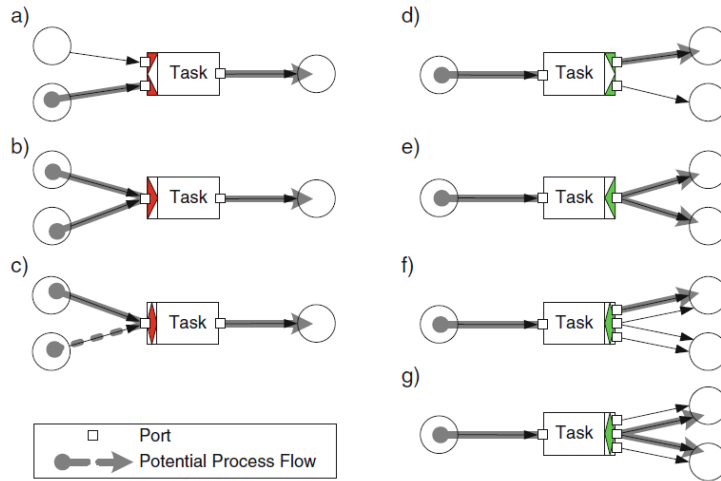


Figure 12: Ports of a YAWL task [36]

Based on the properties just shown, the configuration options for a task with more than one incoming/outgoing process branches are defined as follows [36].

CONFIGURABLE ELEMENT	NO. OF PORTS	CONFIGURATION OPTIONS
AND-join	1	Enabled, blocked, hidden
XOR-join	n	Enabled, blocked, hidden
OR-join	1	Enabled, blocked, hidden
AND-split	1	Enabled, blocked
XOR-split	n	Enabled, blocked
OR-split	$2^n - 1$	Enabled, blocked
Cancellation region	1	Enabled, blocked
Multiple instances		Reduce maximal number of instances, increase minimal number of instances, increase threshold, forbid dynamic creation of instances

Table 4: Configuration options

Configuring the tasks in YAWL is quite straightforward except the OR-Split tasks. An OR-Split task in YAWL may lead to incorrect workflow executions because of the possible multiple choices from an OR-Split task. An OR-Split task can be configured to an XOR-Split, AND-Split or an OR-Split. Figure 5 in the literature review shows three examples of configuring an OR-Split task respectively and the specific rules are described in Section 3.2.

YAWL provides the preview function and generates the final configured process model. No specific knowledge is required to perform the configuration in YAWL, which is very convenient for both the designers and customers.

#### 5.1.2.1 XML Schemas

Comparing the XML codes of a normal task and a configurable task, it is discovered that the following lines are added for a configurable task with nothing else changed. Moreover, adding the configuration-relevant XML codes to a task makes it configurable in YAWL Editor as well. This proves that changing the work specifications can result in the changes in the process model.

```

1 <configuration>
    <join>
        <port value="activated">
            <flowSource id="a" />
        </port>
6    </join>
    <split>
        <port value="activated">
            <flowDestination id="OutputCondition" />
11    </port>
    </split>
</configuration>

```

Moreover, a task is set to default XOR join and AND split in YAWL system.

```

<join code="xor" />
<split code="or" />

```

#### 5.1.2.2 Example

The process in Figure 13 contains OR-Split/Join tasks and in the configurable process, task a, b and d are configurable.

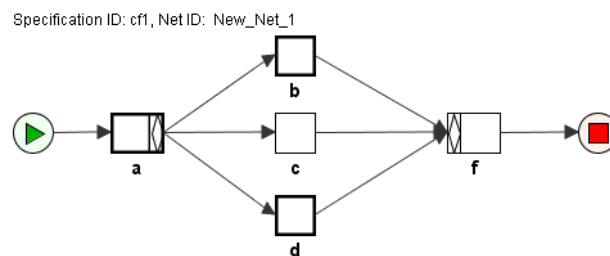


Figure 13: Configurable example

Comparing the XML codes in the workflow specifications, the configuration code of an OR-Split includes all possible outputs of task a, which is corresponding to the choices given by *Output Ports Configuration* as in [Figure 36](#).

```

3  <split>
    <port value="activated">
        <flowDestination id="b" />
        <flowDestination id="c" />
    </port>
    <port value="activated">
8      <flowDestination id="d" />
        <flowDestination id="b" />
    </port>
    <port value="activated">
13     <flowDestination id="d" />
        <flowDestination id="b" />
        <flowDestination id="c" />
    </port>
    <port value="activated">
        <flowDestination id="d" />
    </port>
18  <port value="activated">
        <flowDestination id="b" />
    </port>
    <port value="activated">
23     <flowDestination id="d" />
        <flowDestination id="c" />
    </port>
    <port value="activated">
        <flowDestination id="c" />
    </port>
28 </split>

```

To configure the outputs from task a, it is only required to change the port value from *activated* to *blocked*. The same goes for all hidden tasks. After only activating c, d of task a and hiding task d, task a has a *AND-Split* instead of the original *OR-Split*. And the label of task d is shown as *\_tau*, meaning task d will be skipped when executing the workflow.

Therefore, except the following lines of task a in the XML schemas, the port value of the other six output choices has been modified to *blocked* by YAWL.

```

2  <port value="activated">
    <flowDestination id="c" />
    <flowDestination id="d" />
</port>

```

Additionally, the *join port value* of task d has been changed to *hidden*.

## 5.2 BUSINESS PROCESS CUSTOMIZATION

### 5.2.1 Concept & Theory

Business Process Customization is another approach to manage the process variability which enables more flexibility of process modeling than the configuration approach. A customizable process model is a base process model which collects the most frequently used process variants within a business functions. The base process model allows insertion, deletion, movement and modification by choosing and linking variants. The Provop concept [15] systematically presents the customization approach. In principle, users apply change options to a base process to obtain a customized process. Different customizable processes based on the same base process form the process family of a business function. Unlike the configuration approach, users have more control over the process design. The process owner is only responsible for selecting the process variants of the base process. From the evolved process family, analysis can be carried out to obtain user preferences about the process design.

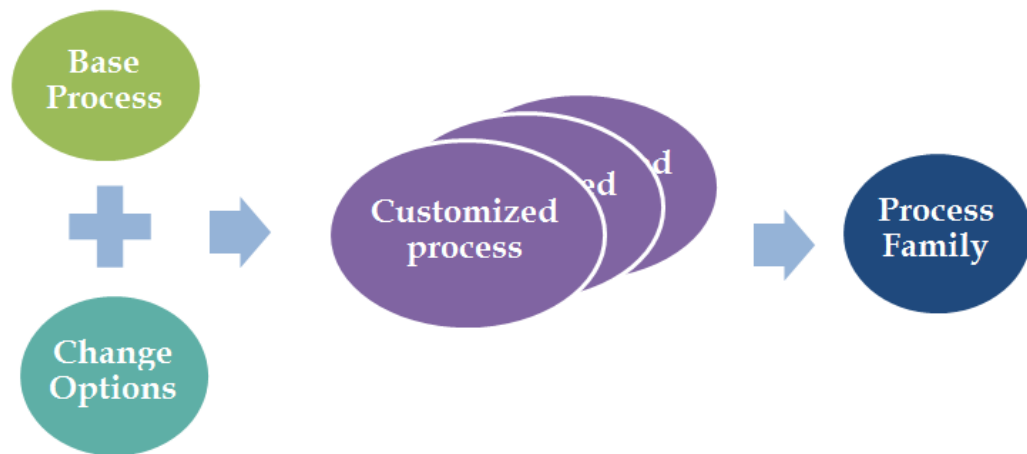


Figure 14: Process customization evolution

The change options that can be applied to a base process are as follows:

#### CO1 - Insert a process variant

**DESCRIPTION:** A process variant is added to a process.

**DESIGN CHOICES:** Where can the process variant be added?

1. between 2 directly succeeding process variants
2. in parallel with 1 process variant or a serial of several succeeding process variants

**CO<sub>2</sub> - Delete a process variant**

DESCRIPTION: A process variant is deleted from a process.

DESIGN CHOICES: How can the process variant be deleted?

1. completely remove from the process
2. set to a null task if removing it affects the whole process

**CO<sub>3</sub> - Move a process variant**

DESCRIPTION: A process variant is moved from its original position to a new one in a process.

DESIGN CHOICES: Where can the process variant be moved to?

1. between 2 directly succeeding process variants
2. in parallel with 1 process variant or a serial of several succeeding process variants

NOTE: Moving a process variant can be broken down to two steps: deleting a process variant and adding that variant to the process in another position.

**CO<sub>4</sub> - Modify a process variant**

DESCRIPTION: The property of a process variant is changed.

**5.2.2 Research Motivation**

Business Process Configuration is an efficient approach to manage the process variability for business, but not sufficient considering the business demands, IT environments, etc. It limits the business flexibility by only allowing a limited amount of process variants to choose from. Lowing the diversity of business decrease customer satisfaction and reduce business reputations [32]. As the business world being more and more customer-driven, customization is able to better satisfy customers. Therefore, process customization is another part of the solution for VI to manage the WMS business processes.

At this moment, not many tools are able to fully support process customization. It is very challenge to develop such tools due to many different reasons and enterprises usually customize their business processes manually. Manual process customization requires substantial modeling effort and constant monitoring as

well as maintenance. To make process customization in a systematic and structured way, a large amount of time and cost must be devoted, not to mention the efforts of reducing the operational risks of customizing business processes which are a lot higher than process configuration. Integrating process variants with a customizable process model demands very extensive knowledge of computer science while implementation for such applications is also not an easy job.

From the BPM point of view, how to ensure the soundness of a process model after customization is a big challenge since anything can be inserted, deleted, moved or modified theoretically on a customizable process model.

VI needs more than just a concept of process customization. Another focus of this project is to research on the development of process customization in YAWL.

### 5.2.3 Proposed YAWL Architecture Extension

YAWL, at this moment, does not support process customization. There is no existing functionality in YAWL that supports the definition of a change option. To be able to insert, delete, move and modify a process variant without manually operating the links in *YAWL Editor*, an external service is required to allow users to freely define and apply a change option to a YAWL model. The YAWL system architecture needs to be extended to allow the Customization Service to interact with the current services in YAWL.

The definition of a YAWL model is supported in *YAWL Editor*, without affecting the other YAWL services. To realize the customization functions, only the workflow specifications on the data layers need to be modified, which has been explained in [Section 4.2](#). To modify the workflow specifications in the *Process Repository*, an external service is required to define and apply the change options to the base process in *YAWL Editor*, meaning creating the XML schemas of the change options and making the corresponding changes in the workflow specifications. Therefore, the Customization Service only interacts with *Process Designer* and its interacted services.

An extended architecture of YAWL is proposed in [Figure 15](#), with a distinguish between the core services and the extended Customization Service.

Inspired by the definitions in the Workflow Reference Model [17], *YAWL Engine* interacts with its services in the through four interfaces. With the specifications from the YAWL developers [36] in [Section 4.2](#), the extended architecture is specified as below. *Process Designer* is the most essential element for the *Customization Service*.

#### Extended services and interfaces:

- *Customization Service* defines and allocates change options to specific positions in the model in *YAWL Editor*.

It interacts with *Process Designer* to access the work specifications of the base process model, obtaining information about the adjustment points, task positions and process workflow.

- *Interface Q* provides endpoints for uploading the base process and unloading the change options.

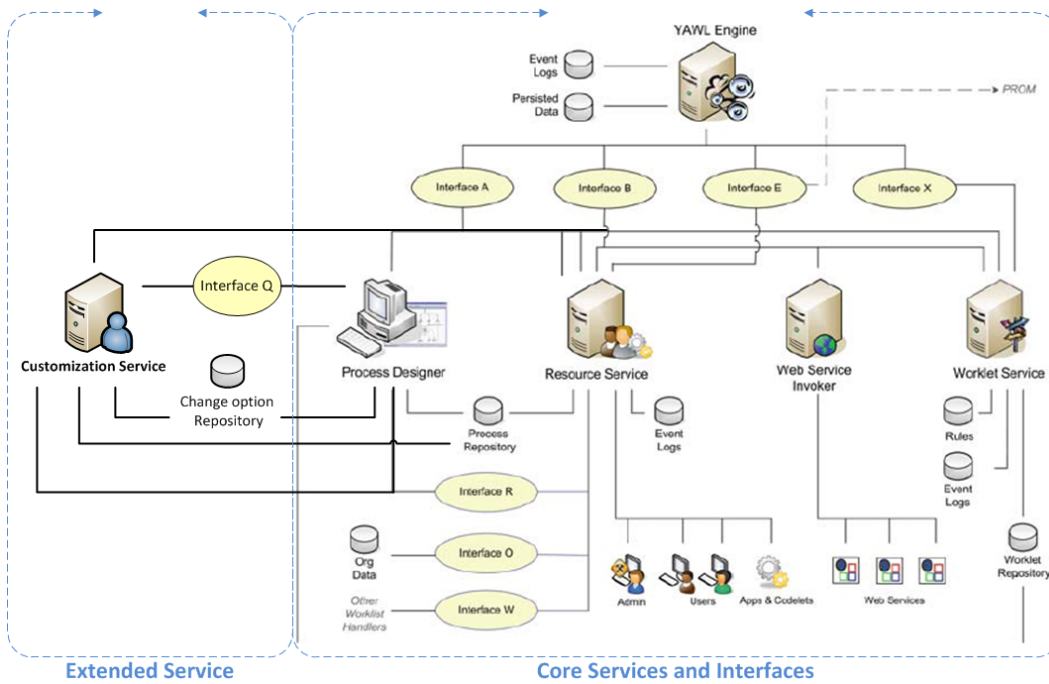


Figure 15: Extended YAWL system with Customization Service

- *Change Option Repository* stores the specifications of defined change options. Definition of change options are generated in XML schemas and stored in this repository.

#### Design choices:

1. *Customization Service* is an external service, which interacts with *Process Designer* and *Resource Service*.

It generates the XML schemas of corresponding change options, accesses the work specifications from *Process Repository* via *Interface Q*, accesses the organizational data from *Resource Service* via *Interface R*.

The user interface of *Customization Service* is embedded in *Process Designer*, like the toolbars in *YAWL Editor*, where you can find process variants.

2. *Change Option Repository*: It is necessary to use a separate repository for change options.

Users can define a change option and choose when to apply the change. If putting the XML schemas of the change options also in the *Process Repository*, the defined changes are separate from the process model when they are not enabled. These separate change options will remain in the work specifications when the work specifications are uploaded to *YAWL Engine*. Mixing the XML schemas of the work specifications and the change options will increase the operational difficulty to integrate with the other services in YAWL.

In this way the customized process models are still uploaded via *Interface A* to *YAWL Engine*. They are able to communicate with other services as

normal YAWL process models via *Interface A*, *Interface R*, *Interface O* and *Interface W*.

3. Another important functionality of the *Customization Service* is to correctly apply the XML schemas of the change options in the XML schema of the base process, changing the input/output port values of the involved tasks at the same time. Following the theory, it is important for the *Customization Service* to correctly identify the position of changes.
4. Via *Interface R*, *Customization Service* has access to the organizational data. Users are able to define the change options related to the organizational data and these changes can be communicated via *Interface R*.

The sets of filters, constraints, allocation strategies, and codelets available to a designer for a task are each pluggable, that is, they can be easily extended so that developers can add new members to the set of each by implementing the appropriate (Java) interface and adding the new class to the *Resource Service* repository. Such additions are immediately available to designers via *Interface R* [34]. Therefore, *Interface R* is able to provide the resource data to *Customization Service* and there is no need for a different interface for this function.

#### 5.2.4 Examples of Process Customizations in YAWL

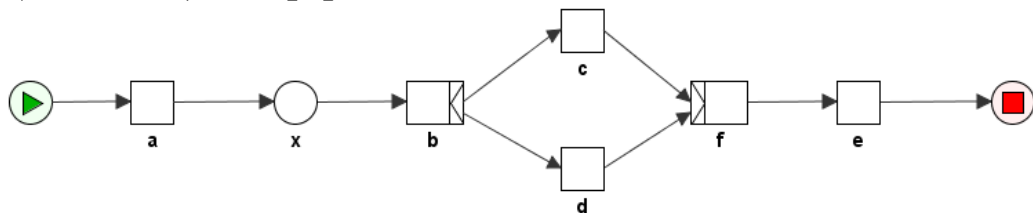
With the proposed architecture extension, a few cases presenting the customization functions in YAWL are demonstrated in this section to show how the changes in the work specifications can reflect in the process model.

Due to time limit of this project and considering the project objective, the extended architecture of YAWL has not been developed. The examples were created by following the architecture principles and making changes in the XML schemas of the work specifications.

##### 5.2.4.1 Base Process

As specified in [Chapter 3](#), the first step of Business Process Customization is to set up a base process, as created below.

Specification ID: ctbase, Net ID: New\_Net\_1



A base process created for customization

#### 5.2.4.2 Adjustment Points

To apply a change option to the base process, the adjustment points in the base process must be defined. A. Hallerbach et al. state that both the entry and the exit of a task can serve as adjustment points [14]. Therefore, when locating the specified change options, only the output and input ports of the the adjoint tasks need to be identified. According to the C-YAWL working theory, the entries and exits of tasks can be regarded as the adjustment points.

B. Weber et al. proposed more change options [37]. Specifically, different scenarios for each change option have been considered. Take insertion as an example. They accounted for serial insert, parallel insert and condition insert. These different types of insertion can increase the difficulty of the technical programming depending on the application itself. However in YAWL, the change options are also formed in the XML schemas and these different types of insertion only hold different values of the input and output ports. Therefore, it is not necessary to distinguish the change options to be developed in YAWL on the same level.

#### 5.2.4.3 Insertion

When inserting a process variant to a base process, the position must be identified first, meaning identifying the output and input ports of the adjoint two tasks where the new process variant will be put in between. In other words, the adjustment points must be identified. In YAWL, there are two types of process variants that can be inserted, a condition and a task. Additionally, the position of a process variant in YAWL Editor is also specified in the XML schemas. The position specifications reflect on the graphic presentation of process variants in the editor. The graphic layout is not important to the research goals, therefore, the positions will not be modified in the examples. Manual movements of the variants are applied to provide a more clear view of the customized process models.

By adding the following XML codes and changing the input & output values of the process variants adjoint to the inserted variants, the customized process is shown in Figure 16.

```

1  ---insert condition z between b and c (serial insert)---
   <condition id="z">
       <name>z</name>
       <flowsInto>
           <nextElementRef id="d" />
6       </flowsInto>
   </condition>
   ---insert task h between b and d (serial insert)---
   <task id="h">
       <name>h</name>
11      <flowsInto>
           <nextElementRef id="d" />
       </flowsInto>
       <join code="xor" />
       <split code="and" />

```

```

16 </task>
    ---insert task g between f and e (serial insert)---
    <task id="g">
        <name>g</name>
        <flowsInto>
21         <nextElementRef id="e" />
        </flowsInto>
        <join code="xor" />
        <split code="and" />
    </task>
26 ---insert task k between b and f (parallel insert)---
    <task id="k">
        <name>g</name>
        <flowsInto>
31         <nextElementRef id="f" />
        </flowsInto>
        <join code="xor" />
        <split code="and" />
    </task>

```

After applying the changes in the XML schemas, conditions *z* and task *h* are inserted after the *AND-Split* task and task *g* is inserted between task *f* and *e*. Also, task *k* is parallel with the other two branches after the *AND-Split*. Figure 16 shows the customized YAWL model with the inserted tasks and condition. The layout of the inserted process variants on the interface of YAWL editor can be also customized in the layout part in the XML codes, which has not been conducted during these experiments.

Specification ID: ctbase, Net ID: New\_Net\_1

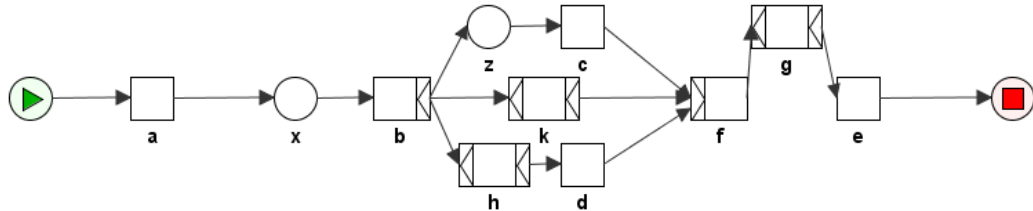


Figure 16: Customized process after inserting process variants

However, there exists an issue after insertion. Since all tasks are default set to *XOR join* and *AND split*, the inserted task *g* shows the *XOR-Join* and *AND-Split* in the editor while the task *g* has no such join and split settings. At this moment, it is not possible remove these two lines from the XML file for the reason that it causes errors in YAWL Engine and the process model cannot be opened again in YAWL Editor. This is one issue that needs to be further studied.

#### 5.2.4.4 Deletion

Similar to insertion, deleting process variants also requires the consideration of the positions and the connections with other process variants in the base process. After removing condition *x* and task *c* and modifying the the input & output

values of the process variants adjoint to the deleted variants in the work specifications, the customized process in Figure 17 indeed removes condition x and task c.

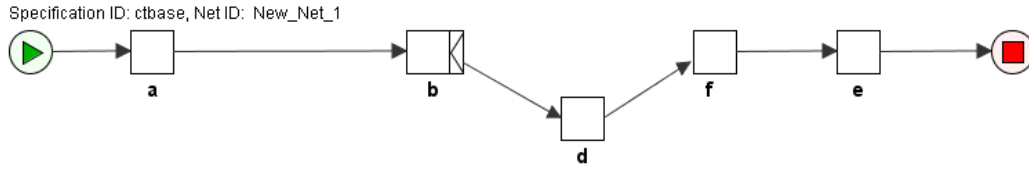


Figure 17: Customized process after deleting process variants

However, task b still keeps the *AND-Split* output port even though the XML schemas have been properly adjusted, while task f has been correctly modified to what is expected. The main guess is because of the default join and split settings in YAWL, which still needs to be studied and improved.

#### 5.2.4.5 Movement

To move a process variant to another position, the first step is to extract the variant from its original position, which equals to deleting the process variant. The second step is to add this deleted variant to a new position in the same process. The example here moves task e to the position between condition x and task b.

```

1  ---move task e between the output port of x and input port of b---
  <task id="e">
    <name>e</name>
    <flowsInto>
      <nextElementRef id="OutputCondition" />
6   </flowsInto>
    <join code="xor" />
    <split code="and" />
  </task>

```

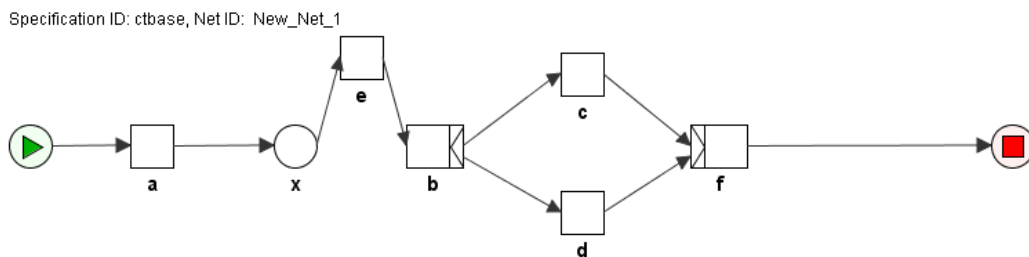


Figure 18: Customized process after moving a process variant

Besides, a subprocess in a base process can also be moved, such as the *AND-join/split* subprocess. The experiment here moves this subprocess to the beginning of the base process.

```

1  ---move the subprocess between the output port of start condition and input
    port of a---

```

```

<task id="b">
  .....
<task id="f">
  .....
6 </task>

```

Specification ID: ctbase, Net ID: New\_Net\_1

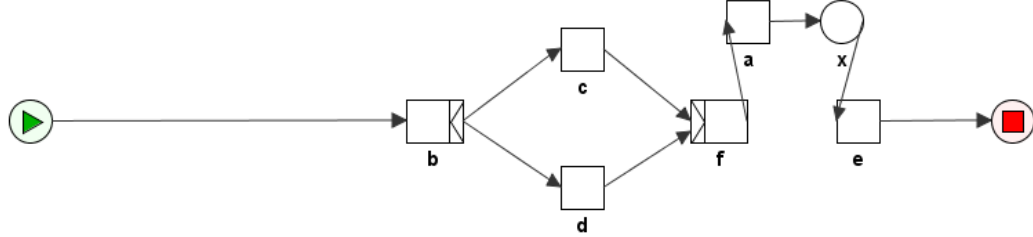


Figure 19: Customized process after moving a subprocess

#### 5.2.4.6 Modification

In the YAWL work specifications, only the workflow information is recorded. Therefore, only the *name* value of tasks and conditions (and positions in the Editor) can be modified via the XML schemas. The example here changes the *name* values of task a and condition x in [Figure 20](#).

Specification ID: ctbase, Net ID: New\_Net\_1

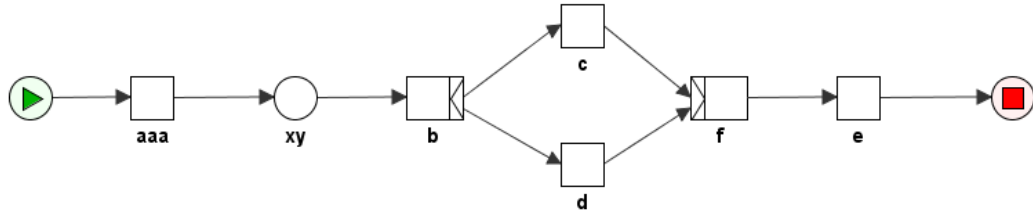


Figure 20: Customized process after modifying process variants

#### 5.2.4.7 Special Cases

The insertion and deletion examples both show the same type of issues about the split/join tasks during customization. Because of the default settings by YAWL, simply changing the XML schemas do not produce the expected results. Here is an unsuccessful experiment of changing task b to *OR-Split* and task f to *OR-Join*, the process model does not preserve the soundness or correctness, see [Figure 21](#). In this example, the problem more than the soundness of a process. The customized process does not even show a complete and connected workflow.

The issues discovered during the research experiments in this project are related to the soundness preservation of a process model. Unlike the examples presented previously, the customizations on tasks with more than 1 incoming/outgoing process branch in the XML schemas do not always show the expected changes in

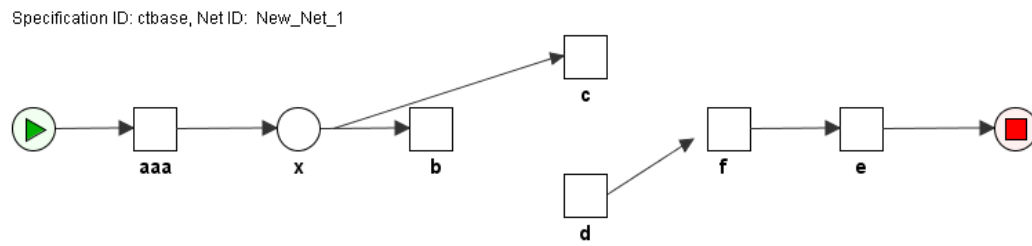


Figure 21: Customization limitation of join/split tasks

*YAWL Editor*. How to preserve the completeness and soundness of customized processes is a research topic that needs to be further studied.

### 5.3 CASE STUDY

#### 5.3.1 Current Situations

As introduced in [Chapter 1](#), VI designs and manufactures WMSs. To be able to design and manufacture the physical equipments for a WMS, the business functions supported by a WMS must be defined in the first place, which is normally achieved by collecting the customer requirements. In other words, the business processes of a WMS are defined first in order to check whether the specific requirements are met with the infrastructure layout that will be designed afterwards. Normally, VI collects the customer requirements in texts and draws up the infrastructure layouts based on the textual descriptions. Sometimes, business processes were modeled in an unstructured way between these two steps; nevertheless, VI does not have a standard process modeling approach. The design approach used by VI is shown in [Figure 22](#).

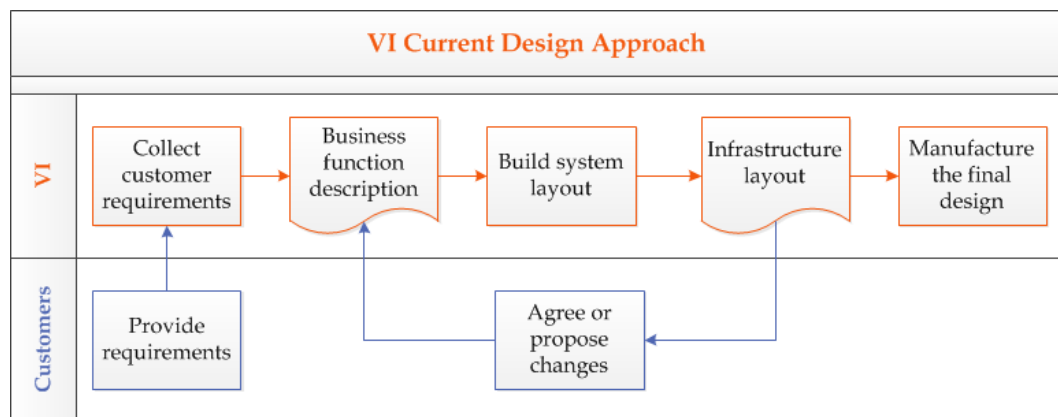


Figure 22: The current design approach at VI

The consequences of this are that VI has to record the requirements in texts for each customer and converting the textual requirements to the infrastructure layouts takes too much time and resources, especially when many designs share a lot of business processes in common. It is time consuming to convert the business processes from the textual descriptions to the mechanical designs. When a system designer wants to review the business processes from the existing solutions, it is also difficult to extract the correct information from texts. Furthermore, it increases the difficulty to communicate with its customers and business partners since they do not have adequate knowledge in this area. Once a change is required from a customer or business partner, it again requires a lot of time and efforts.

Since VI's core value is design, a unique WMS solution is provided to each customer to satisfy their business demands. The WMSs designed by VI share the same high-level structure just as the example described previously and have quite many processes in common. However, many details like functional and non-functional requirements can vary largely and make a difference to the business processes. Different customer requirements are reflected mostly in the system

designs instead of the business functions. Therefore, the VI WMSs share many similar functions but also differ in various ways.

VI system designers start a new design from scratch even though it shares some processes in common with the other existing solutions. There exists no standard WMS business processes for them to adapt to achieve a customized solution. Because of complexity, it takes a lot of time and effort to design the business processes of a WMS for each customer.

### 5.3.2 Warehouse Business Processes

With YAWL and the information provided by VI, the configuration and customization approaches were applied for the WMS business processes in the fashion and small-sized goods domains.

For the reason of confidentiality, very specific design information from the VI WMS was removed from the developed solutions. Therefore, the examples demonstrated here are not the complete original solutions developed for VI, but based on the VI scenarios.

A WMS contains five classic modules and each module consists of a number of business processes. Briefly, the WMS classic modules are described in [Table 5](#).

MODULE	DESCRIPTION
Receiving	A WMS process always starts with receiving goods from suppliers and distinguishes between new items and returns. All new items are registered and quality control is applied to all returns. Received goods can be either stored or directed to packing immediately. Goods to be stored are transported to the storage area.
Storing	There are different storing methods, such as storing based on types, storing based on fast-picking algorithms, etc.
Picking	There are different methods based on the customer requirements, for example separating single-item orders (SIOs) multiple-items orders (MIOs).
Packing& Consolidation	Standard packing and gift packing are two different procedures. Gift packing is manually accomplished while standard ones are automatically done by machines. After packing, all orders will be weighed and labeled with addresses automatically. Then all packages are sorted to specific destination gates for shipping.
Shipping	Loading packages to trucks is the last step within a WMS. Based on different customer situations, the order bills can be transferred to another IT system afterwards.

Table 5: WMS module descriptions

To provide a clear overview, the examples are constructed with hierarchies. A WMS always uses the same structure as in [Figure 23](#). The examples created here are about a WMS in the small-sized goods business.

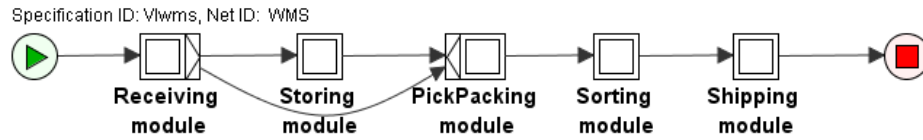


Figure 23: WMS example - high-level structure

### 5.3.3 Configuration Solution

A configurable process model of the WMS business processes contains some extra variant options defined in [Table 6](#). The configurable WMS process model is shown below. In [Appendix B](#), the process models are presented with a more clear view.

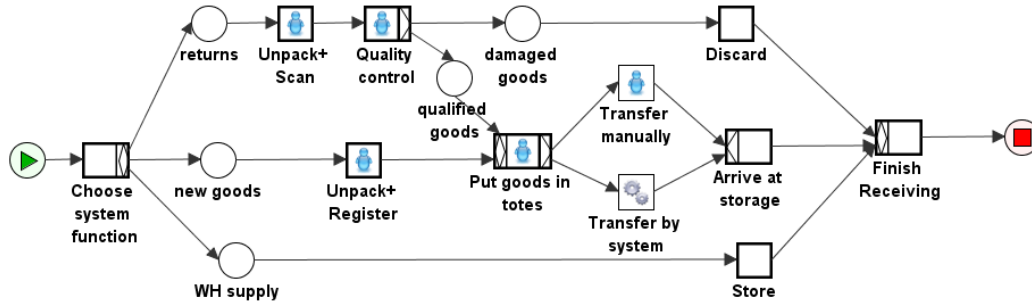
MODULE	EXTRA OPTIONS
Receiving	A unique serial number is added to a new item for tracing and tracking.
Storing	There are two algorithms: fast picking and category-based.
Picking& Packing	<p>There are two picking methods.</p> <ol style="list-style-type: none"> <li>1. Mix all orders and let the packing operators separate to customer orders.</li> <li>2. Separate single-item orders (SIOs) multiple-items orders (MIOs). SIOs are picked and directly sent to packing while MIOs are picked together, sent to packing operators and separated to customer orders there. Afterwards, they will be sent to packing.</li> </ol>
Sorting	Sometimes, the consolidation and packing orders can be reversed.
Shipping	Loading orders to trucks can be done either by operators or machines. After loading, the process for a WMS ends.

Table 6: Configuration options

In reality, a customer does not always want a complete WMS solution. Sometimes customers just need to replace some parts of their existing systems to increase the WMS performance and save cost. Therefore, the choices in [Table 7](#) are applied to the given configurable WMS process:

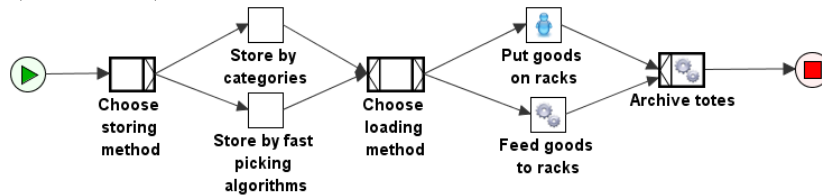
And the configured WMS process looks like below. It does not take much time to configure an individualized process model from the given configurable model.

Specification ID: Vlwms, Net ID: Receive



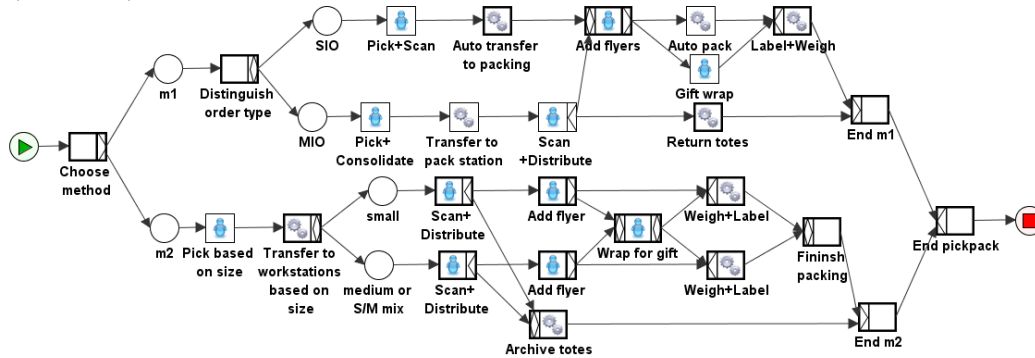
Configurable WMS - Receiving Module

Specification ID: Vlwms, Net ID: Store



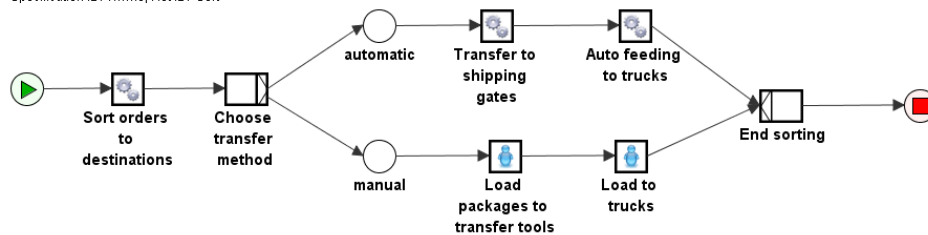
Configurable WMS - Storing Module

Specification ID: Vlwms, Net ID: PickPack



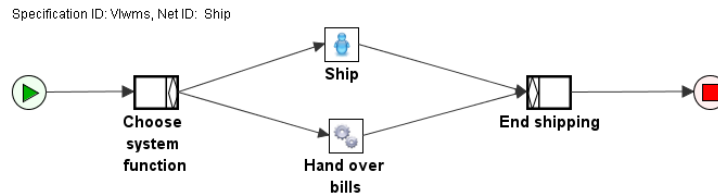
Configurable WMS - Picking&amp;Packing Module

Specification ID: Vlwms, Net ID: Sort



Configurable WMS - Sorting Module

And YAWL provides an overview of the configured WMS business processes as well.



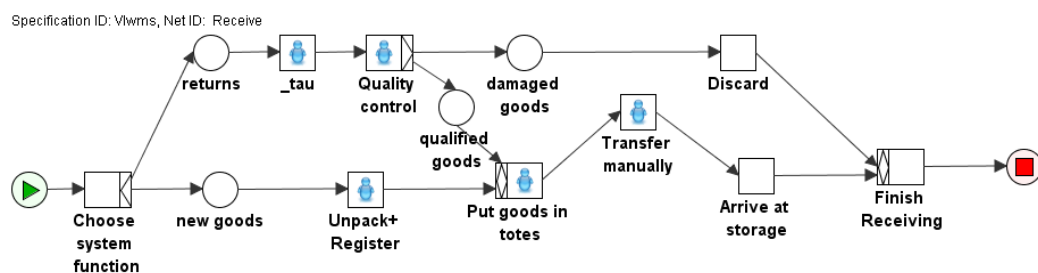
Configurable WMS - Shipping Module

MODULE	EXTRA OPTIONS
Receiving	<p>The function for handling <i>WH supply</i> is not needed.</p> <p><i>Unpack+Scan</i> is not necessary for returns.</p> <p>Goods in totes is transferred <i>manually</i>.</p>
Storing	This module is not needed.
Picking	<i>m1</i> is chosen to handle the picking and packing procedure.
&	<i>Add flyers</i> is not chosen.
Packing	Goods in totes is transferred <i>manually</i> .
Sorting	<p>Packages are <i>automatically</i> transferred to shipping gates.</p> <p>The automatic <i>feeding equipment</i> is not necessary (the customer already has the equipment).</p>
Shipping	There is only one IT system for the WMS, so there's no need to <i>Hand over bills</i> to another IT system.

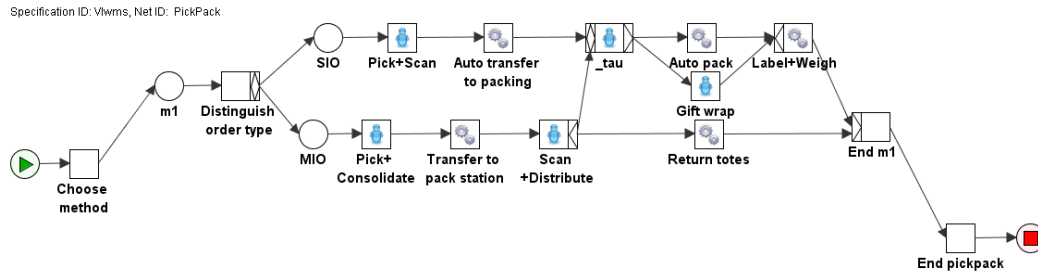
Table 7: Applied configuration choices



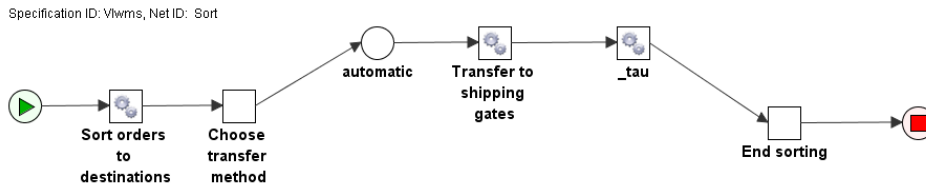
Configured WMS high-level structure



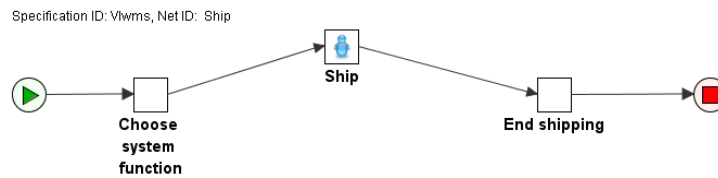
Configured Receiving Module



Configured PickPacking Module



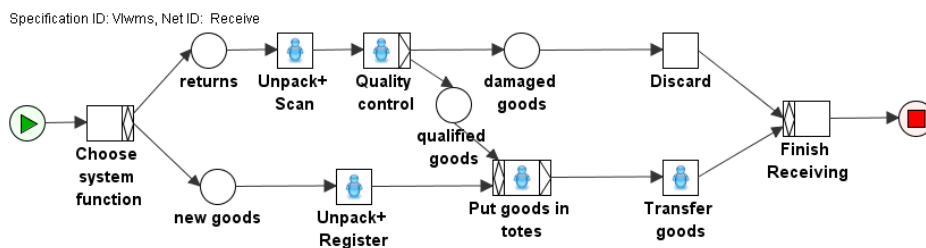
Configured Sorting Module



Configured Shipping Module

#### 5.3.4 Customization Solution

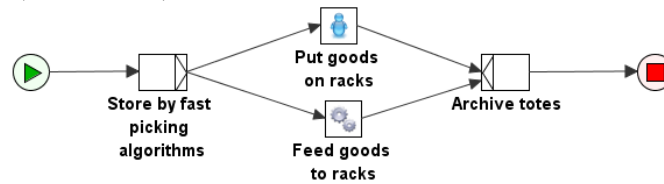
The base process is also constructed like the configurable process in hierarchies. A base process consists of the most frequently used process variants and in the base process created here shares the same high-level structure with the configurable process, which is [Figure 23](#). And the change options are defined in [Table 8](#).



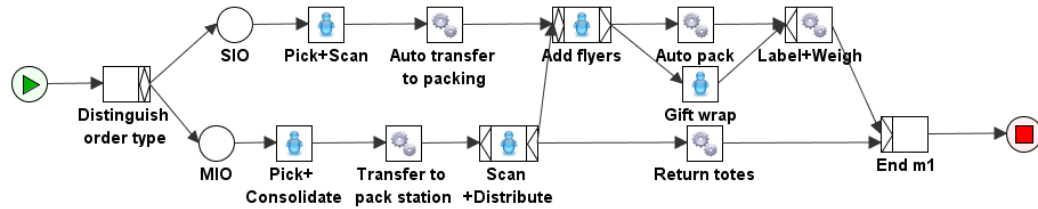
Base process - Receiving Module

The customized WMS process model shows more business options than the configured WMS process. The example here only defines a few new process variant, but in real life, there can be many more business choices. Only with the customization approach, the new options can be easily adjusted to the process.

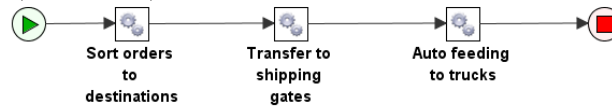
Specification ID: Vlwms, Net ID: Store



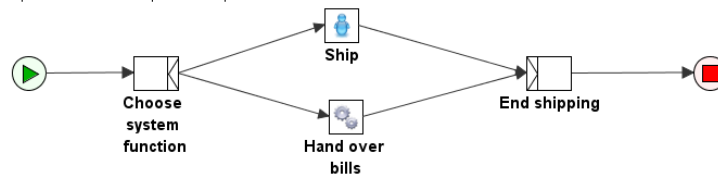
Specification ID: Vlwms, Net ID: PickPack



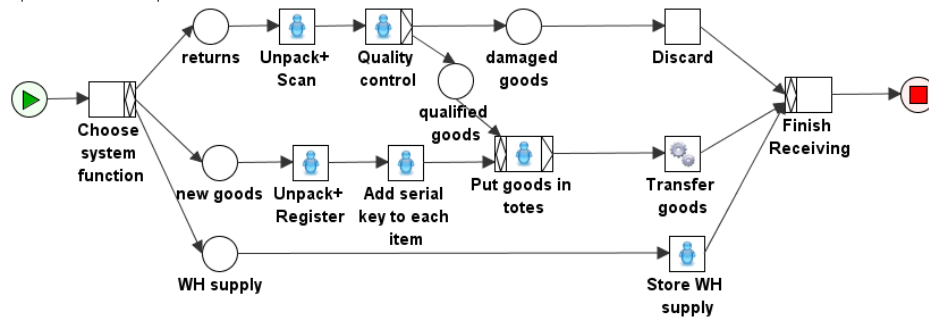
Specification ID: Vlwms, Net ID: Sort



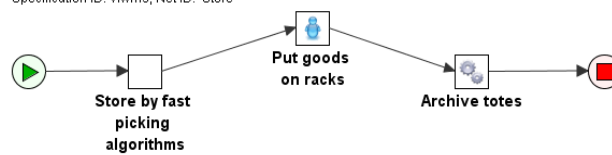
Specification ID: Vlwms, Net ID: Ship



Specification ID: Vlwms, Net ID: Receive

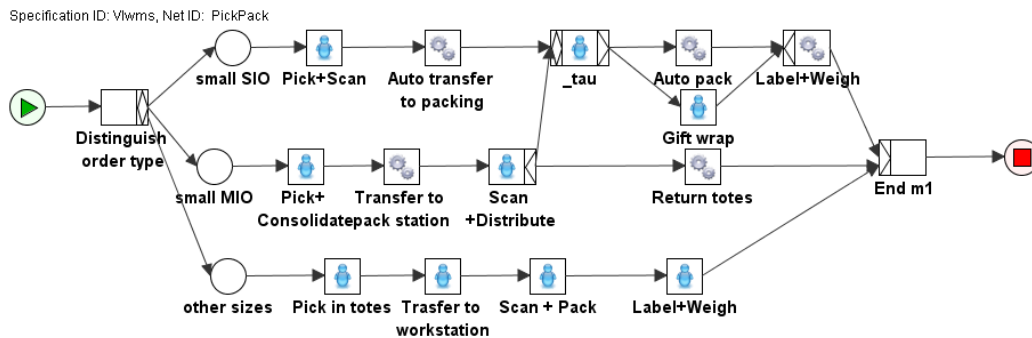


Specification ID: Vlwms, Net ID: Store

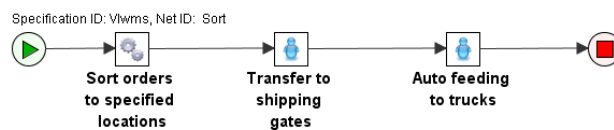


MODULE	EXTRA OPTIONS
Receiving	<p><b>Add</b> serial key to each item for easy tracing of goods</p> <p><b>Insert</b> the function of handling WH supply, including Store WH supply</p> <p><b>Modify</b> Transfer goods to automated</p>
Storing	<p>Only allow loading goods <i>manually</i>, <b>deleting</b> Feed goods to racks</p> <p><b>Specify(modify)</b> Archive totes to automated</p>
Picking&Packing	<p><b>Insert</b> a process branch after Distinguish type, including Pick in totes, Transfer to workstation, Scan+Pack, Label+Weigh, all manually</p> <p><b>Delete</b> Add flyer by changing the task to a null task</p>
Sorting	<p><b>Modify</b> Sort orders to destinations to Sort orders to specific locations</p> <p><b>Modify</b> Transfer to shipping gates and Auto feeding to trucks from automated to manual</p>
Shipping	<b>Move</b> Hand over bills from parallel to Ship to after Ship

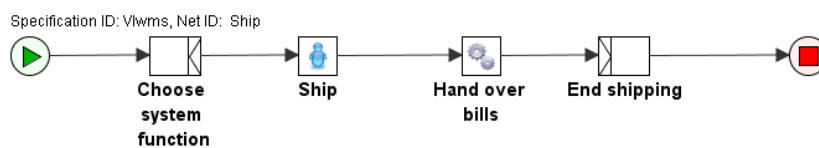
Table 8: Customization change options



Customized Picking&amp;Packing Module



Customized Sorting Module

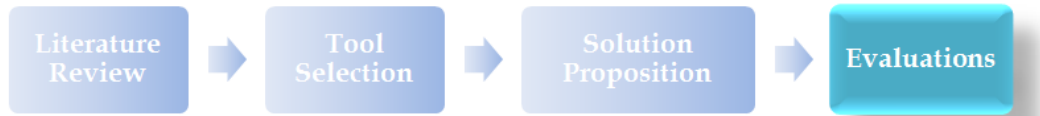


Customized Shipping Module



## EVALUATIONS

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As the final step, the feedbacks from VI and the comparisons and analysis of Business Process Configuration and Business Process Customization against the findings from the literature view and VI feedbacks are presented.

### 6.1 FEEDBACKS FROM VANDERLANDE

To evaluate the configuration approach as well as C-YAWL, a demonstration of how to configure the WMS business processes in YAWL was given and feedbacks were collected during the open discussion sessions. Surveys were sent out after the demonstration to collect feedbacks and suggestions.

In the surveys, it was investigated how VI evaluated Business Process Configuration and Business Process Customization, such as how the approach(es) can help VI with internal efficiency, benefits and concerns of both approaches and what to be improved. Valuable evaluations were received from the department manager, senior system engineers/designers and sales consultants, etc.

Part of the feedbacks were received from a senior System Engineer and an experienced System Designer (which is called Sales Consultant at VI). They are responsible for designing the WMSs and communicating with customers, who have both worked on a large number of customer projects and very familiar with the whole procedure, from design to final installations. Their opinions are representative.

The collected opinions provided practical insights into the approaches as well as the software application. The VI evaluations are presented in three categories: configuration approach, customization approach and YAWL application. For each category, the strengths and weakness have been summarized, which are presented in a table following explanations.

#### *Configuration approach*

**Benefits:** Business Process Configuration brings an innovative thinking of process design/modeling to VI and it is considered to be very beneficial for VI to apply in practice.

- It provides *process standardizations* in addition with *some design flexibility*, especially when the WMS processes are complicated and large.

BENEFITS	Provide a complete overview for easy understanding
	Provide process standardizations and allow some design flexibility
	Reusable and can be regarded as a library of existing solutions
	Bring better insights to design scope and cost
	Time-efficient and cost-effective for design
DRAWBACKS	Limited design flexibility
	Time-consuming to collect all existing solutions to construct the configurable model
	Business processes are not completely connected with mechanical installations.

Table 9: VI evaluations of Configuration

- Compared to the VI design approach, a process model is *easier and faster to check* the business processes than reading from texts.
- A configurable process model is *reusable and regarded as a library* of the existing solutions.  
It only needs a *one time construction* and the new variants can also be added afterwards.  
From the resource and time perspectives, reusing what has already been specified, built and tested is more *efficient and effective* than re-doing.
- Apart from reducing the design effort, process configuration is also able to *bring better insights into the project scope and cost* for the process designers.
- Most importantly for VI, process configuration is *much more cost effective*.  
Using a standardized process control software is able to save cost for the company while improving the design and modeling efficiency at the same time.

On the other hand, process configuration enables better communications with the external parties. It fastens up the communications and discussions which will save the design time and resources for VI. This also reflects directly on the cost reduction, which is a plus point.

- A configurable process model contains *straightforward business processes* instead of infrastructure designs. Customers with little WMS knowledge can *understand* the business processes *faster and more easily*.
- The configurable process models also *provide a complete view* of the business processes of a WMS for customers.

- Instead of discussing the infrastructure layout with customers, VI is able to discuss and modify the business processes before constructing the infrastructure layout.

The *design time is highly reduced while the quality of design is improved*, increasing the design efficiency and effectiveness. With a better understanding of the design, customers can ask for changes to make sure the designs will be satisfying.

#### Drawbacks:

- The biggest drawback of Business Process Configuration is that it *limits the design diversity*, which *cannot fulfill VI's business missions and ambitions*

This is a fatal flaw for the WMS business since the WMS processes are the least standardized processes and VI provides customized designs. The WMSs are very much dependent on the surrounding systems, e.g. equipments, user interfaces, customer host stems, etc. Variants in a configurable process model cannot be moved or modified and new variants are not allowed to be added.

Therefore, process configuration can only *be the start of the design for VI*. In addition to the configured processes, customizations will always be needed to satisfy VI's business demands.

- Another concern points at *the connection between the configurable process models to the mechanical domain knowledge*.

VI communicates with its customers and business partners by using the configurable business processes instead of the mechanical infrastructure layouts. Completing a WMS business process model is not the end of a project. There is still a gap between the business processes and the mechanical installations.

However, linking process modeling to business domains is out of the scope of this master project, therefore it will not be further discussed.

#### Customization approach

BENEFITS	High design flexibility and business diversity
	Allow customers to be active in design and increase business satisfaction
DRAWBACKS	Too much design freedom might increase cost and risks.

Table 10: VI evaluations of Customization

**Benefits:** Customization is the current design method which is conducted manually at VI.

- It allows *a high degree of design freedom and system flexibility*, which meets very specific customer requirements.

- Involving customers in the design help *increase customer satisfaction*.
- It *fulfills business demands* of VI and cannot be removed.

**Drawbacks:**

- It takes *a lot of time and resources* to do process customization.
- Giving too much freedom to customers might *increase the design cost and risks*.

Therefore, the customized business processes must be checked and validated by VI to limit cost and reduce risks.

*YAWL application*

BENEFITS	Easy access and handy to operate
	Licence-free
	More services/functionalities can be developed.
DRAWBACKS	Cannot provide data insights

Table 11: VI evaluations of YAWL

**Benefits:**

- The YAWL tool is evaluated as *easy to access and operate*.  
The way that process configuration works in YAWL is straightforward and it does not require extensive knowledge.
- The application is also *free of licence and can be further developed*, which can help VI save cost.

**Drawbacks:**

- However, YAWL is *not able to provide data insights* of the WMS process.  
It was discussed that YAWL does not support data simulation in such way that VI can immediately calculate the system capacity, required human resources, etc. It is possible that VI will consider another tool which supports both process configuration and data simulation for its business convenience.

*Summary*

To sum up, Business Process Configuration will innovate the current working style at VI and highly improves the design efficiency and accuracy. However, the limitation of business flexibility has a negative impact on the company reputation. Therefore customization of the business processes is obligatory after configuration to meet customer satisfaction.

## 6.2 COMPARISONS & EVALUATIONS

Through the examples and VI feedbacks, it was able to evaluate the two approaches against what was learnt from the literature review. The literature review was concluded with [Table 2](#) in [Chapter 3](#), stating the advantages and drawbacks of each approach. The table is repeated here in [Table 12](#).

		ADVANTAGES	DRAWBACKS
CONFIGURATION	O	Little design effort with a configurable model	Challenge of modeling the configurable process
		Manageable maintenance and supports	Limited variant options
		Low risks of operational errors of implementation and integration	Difficult to add variants after implementation
CUSTOMIZATION	S	Cost effective and control at business side	Low business diversity and customer attraction
	O	Visibility of the business process variability	Huge design effort
		High flexibility of the business processes	High cost and lead time
			Constant monitoring and supports
			High risks of operational errors
	S	High business diversity and customer satisfaction	Legacy systems issues during the process family evolution
			Little control at the business side

*O=Operational, S=Strategic*

Table 12: Evaluations - Configuration vs. Customization

### *Strategic Perspectives*

1. Business Process Customization provides more flexibility of process design and enables business diversity than Business Process Configuration.

- Configurable models created by companies limit the freedom of process modeling even though they can also improve the communications between the two sides. Clearly, they only provide a certain number of choices while the customizable models have no limits. It is more flexible to design the

WMS with a customizable process model and able to meet VI business demands, since a WMS is very dependable on its surrounding environments.

- The design flexibility of the customization approach is able to highly increase the business diversity, which satisfies the customers very well nowadays. Customers feel more important in the business with the customization approach since they have more control over the design.

With more flexibility, customization improves the business performance better than configuration. For companies like VI that needs very customized business solutions, Business Process Customization is more beneficial to communicate with customers while Business Process Configuration can be used internally to create process standardizations and design library.

2. It is not completely true that there is little control over customized processes at the business side.

- In the literature review, one strategic disadvantage of Business Process Customization is little control of process customization.
- However, companies still hold the final control over customized business processes. Customers are free to individualize their desired business processes. Companies check the customized business processes afterwards to ensure the correctness of the design, limit the cost and reduce risks, which was commented in the VI surveys.

It is not always reliable to fully hand over the design control to customers, since they might not have adequate knowledge to ensure the design correctness. Enterprises like VI have the knowledge and resources to check customized designs and they will carry out the checks to make sure the design is consistent, sufficient and cost-effective for their customers.

### *Operational Perspectives*

1. Business Process Configuration requires less design effort, even though it could be challenging to construct the configurable process models.

- It is proven to be true since the configurable WMS process model is obviously more complicated than the base process, since it covers all possible choices.
- It takes longer time to combine all the choices into the configurable model and it is just a generic example that does not show all the business processes in real life which are much more complex.

2. However, it is more challenging to construct a configurable process model than a base process for customization.

- A configurable process model contains all possible business choices. For enterprises like VI, there are large quantities of business options and existing designs. It can be very time-consuming to collect all options.

- A base process only consists of the most frequently used process variants. Even for very complicated systems, it is not difficult to find out the most frequently used process variants, like the WMS classic modules.
3. Business Process Configuration can be used to develop a library of existing business options and it is also cost-effective. This former point was summarized from the case study which does not exist in literature review.
- The configurable process models are developed by companies to provide existing business choices. With proper organizations, it provides a library of business options and references for new designs. This can reduce time for new designs.
  - Since less effort is required, Business Process Configuration is able to reduce design resources and time, which brings cost reductions to organizations. It is always a positive point, which is one of the positive evaluations from VI as well.
4. The customization approach requires constant monitor and supports while it is easy to maintain the configurable process models.
- The soundness and semantics of a configured process model can always be guaranteed once the configurable model is sounded and logic. There is no need for constant monitoring and support like the customization approach.
  - When adding and moving process variants, especially by customers who do not always have adequate knowledge, the soundness and correctness of the customized processes must be verified and validated.
  - The logic of a customized process can be validated with domain-specific knowledge, but the soundness check can be very challenge if the model is very complex and large.
- VI system designers can check whether the business processes of a WMS are reasonable and correct, however, checking the process soundness is not their expertise.
5. The risks of operational errors for process customization are a lot higher compared to the configuration approach.
- Unknown process variants can be added to the base model by customers, which might cause very fatal failures.
  - Although the risks for the configured processes are lower, it is not always easy to adjust the configurable processes. It requires soundness check if any variants need to be added and the legacy system issue must be taken into consideration if any implementation has been carried out already.

6. The two approach can complement each other. Combing two approaches can be practical and beneficial, which is not mentioned in any literature. The selected papers all focused on one approach, either Business Process Configuration or Business Process Customization.

As discussed with VI, Business Process Configuration is able to improve the design efficiency and configurable process models can be reused, which also saves time and relevant resources. However, the limit of business flexibility is very serious which requires customization after configuration. Combining the configuration and customization approaches can solve this problem:

- Applying the configuration approach enables organizations to quickly obtain a process model which meets some of the customer requirements from existing solutions.
- Adding customized process variants to the configured process model further meets all customer requirements.

This combined approach speeds up the process of achieving a customized process model by taking advantage of the existing business choices and complements the limitations of process configuration

To sum up, the VI case study verified and validated most of the review findings from the selected academic papers. It proved that Business Process Customization is a more flexible and attractive approach which requires more effort and time. It is more beneficial for large organizations and enterprises which focus on customizing business and increasing customer satisfaction. The configuration approach helps to set up a library of existing business options, which provides references for new designs. Business Process Configuration is also more cost-effective, which is suitable for small and medium organizations who needs more standardizations than individualizations.

### 6.3 RECOMMENDATION

A recommended approach for organizations to manage the variability of their business processes is to start with the configuration approach and then apply process customization to ensure the business flexibility and customer satisfaction.

- Business Process Configuration improves the design quality, reduces cost and resources and enables better communications with customers and business partners.
- Configurable process models contain some standardizations and also provide certain business choices, which can be seen as a library of the existing solutions to provide references for new designs.
- Applying the customization approach after process configuration enable VI to keep providing customized designs to its customers, which keeps it competitive in the WMS business.

This combined approach is also suitable for big organizations with difficulties to manage business process commonality and variability. Given the current development of BPM technologies and available technological solutions, combining process configuration and customization is very beneficial from the perspectives of working efficiency, cost and business performance.



## CONCLUSIONS & FUTURE WORK

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The final chapter of this thesis summarizes the achievements of this project. It concludes the work that has been done and answers the research questions set in [Section 1.2](#). The thesis ends with the current limitations and recommendations for the future work.

### 7.1 CONCLUSIONS

The main objective of this project is to help industry manage the commonality and variability of their (large and complex) business processes. By conducting an literature review, two approaches that match the research goals, Business Process Configuration and Business Process Customization, were analyzed. By evaluating these two approaches in a case study of Vanderlande Industries (VI), the following conclusions were made with respects to the research questions proposed in the beginning.

#### **RESEARCH QUESTION 1 : What are the benefits and drawbacks of Business Process Configuration and its impacts on organizational practices?**

Business Process Configuration maintains standardizations which enable organizations to improve modeling efficiency and effectiveness and at the same time provides some process flexibility. It saves modeling cost and reduces modeling errors.

However, it takes time to construct the configurable models, collecting all possible process variants. More significantly, it limits the process flexibility with the business side providing only a certain amount of choices, which highly decreases the business diversity and customer satisfaction.

#### **RESEARCH QUESTION 2 : What are the benefits and drawbacks of Business Process Customization and its impacts on organizational practices?**

Business Process Customization enables a high degree of process flexibility and business attraction. Users can insert, delete, move or modify process variants on a base process model. However, the available technological solutions only provide limited supports because of the integration and implementation difficulties. It is very challenging to ensure the process soundness and also requires constant maintenance. This approach requires additional cost and time.

#### **RESEARCH QUESTION 3 : Which are the similarities and differences between Business Process Configuration and Business Process Customization?**

Both approaches provide more flexibility of process modeling than the traditional modeling approach. They make it efficient and effective for organizations to model large and complex business processes.

[Table 2](#) shows the comparisons between the two approaches. Strategically, customization enables a much higher degree of flexibility than configuration, which

makes a big difference on business attractions and customer satisfaction. Operationally, the configuration approach is more cost-effective, time-efficient, better supported and easier to maintain. The control of process configuration lies with the business side while customers have more control with the customization approach. Process customization has not been well supported yet, for the reason of the integration challenges, soundness difficulty and a larger quantity of maintenance is required.

From the academic point of view, Business Process Customization can be seen as an evolution of Business Process Configuration despite the owner of control. Both approaches require certain variant points to realize the configuration/customization.

Business Process Configuration is more organization-oriented while customization is more customer-oriented. For small and medium business, the configuration approach is better and safer since it requires less cost and maintenance. Process customization is more beneficial for large enterprises which have more financial capabilities and need customized products to meet customer requirements. A possible solution for organizations to take advantage of all strengths is to let a customer customize a desiring process model and at the same time configure the process internally. Afterwards, the configured process is compared with the customized one to find out the differences. With modifying and negotiating, a final process model that consists of parts from the two process models is able to satisfy both parties.

**RESEARCH QUESTION 4 : What are the available technological solutions for Business process configuration and/or Business process customization?**

YAWL was selected to construct the configurable process model for VI, because of its extensive functionality, straightforward modeling language, simple system requirements and IT environments as well as the personal experiences compared to EPC, as in [Table 3](#).

There exist not many tools to fully support customization functions. AristaFlow BPM Suite is a capable tool but only free for research purposes. Given the situations of this project, YAWL was chosen to extend a Customization Service to enable process customization.

Moreover, a tool supporting both configuration and customization is more convenient and cost-effective for industrial organizations.

**RESEARCH QUESTION 5 : How can the configuration and customization approaches be applied to a specific business scenario?**

This is achieved by applying a case study of VI's Warehouse Management Systems (WMSs). First of all, the business processes were analyzed as well as the reasons why VI needed such a structural approach. As a result, a deep understanding of the process variability was obtained.

On the other hand, it was learned that tasks can be modified to configurable in the work specifications of the YAWL models that are saved in XML schemas. With the information by VI, the configurable WMS process model was constructed in YAWL. An extended YAWL architecture was proposed with the Customization

Service and it was considered mandatory to use an external service. It was proven with experiments that changing the XML schemas of the work specifications can trigger customizations in the process model in YAWL Editor. Due to time limit, the Customization Service was not implemented.

By comparing a configurable WMS process model and a customizable one based on the VI scenarios and analyzing VI feedbacks, the advantages and drawbacks of Business Process Configuration and Business Process Customization from the literature review were confirmed.

Business Process Configuration is more efficient than VI's current design approach. Moreover, configurable process models can be used to set up a library of existing designs, which provides references for new designs. They are also easy to understand and communicate with external parties. However, it cannot fulfill diverse business demands, therefore customization is needed afterwards.

Different from the literature review, the control of process customization is not necessarily at the customer side. The customization approach allows customers to individualize their desired business processes, but in the end, companies still need to check the correctness for business performance.

With the analysis and feedbacks from VI, a combined approach could be beneficial for industry, which is to start with Business Process Configuration and apply Business Process Customization afterwards to meet all customer requirements. This combined approach increases the design efficiency with the configuration approach to achieve a certain amount of standardizations and ensures the process flexibility with customizing the configured business processes.

## 7.2 FUTURE WORK

Future work for the limitations noticed during the project is considered. Hereby the limitations and future work are presented from the business and research perspectives.

How to make a choice between Business Process Configuration and Business Process Customization for organizations is not as easy as it seems to be. It requires considerate evaluations of the strategic and operational capabilities of an organization and comprehensive Risk Management. Although the customization approach is helpful to increase the customer satisfaction, the real question for organizations is "*Do we have the capability and resources for Business Process Customization?*" Considering the unexpected variance of business processes and higher customer expectations, how to efficiently model a customizable base process and capture all options for a business function is a challenge, and it requires more comprehensive market investigation and business analysis.

A very interesting direction for research is how to preserve the soundness of customized processes. As analyzed previously, the soundness of configured processes can be guaranteed with considerate designs of configurable process models. However, this is not the case for customization. A user can make any kind of changes to a customizable process model, resulting in unknown process structures. As a consequence, the soundness and semantics of a customized process

cannot be guaranteed. Even though YAWL is able to validate the process after customization, it is still not a sufficient solution. In this way, more time and cost will be required to verify and validate the customized process models. From the BPM point of view, it is reasonable, highly beneficial and convenient to check the soundness during customization.

Business analysts are also concerned with linking domain specific knowledge to configurable processes models. Although it is out of the project scope, it is still an interesting topic to make business more convenient and efficient for industry.

In the end, my work can be further evaluated by business experts and academic researchers who are interesting in the topic of managing business process variability. It will bring more insights and help to improve my work.

Part III

APPENDICES



## ADDITIONAL FIGURES

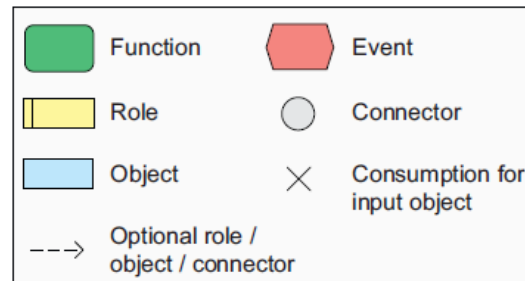


Figure 24: EPC elements [24]

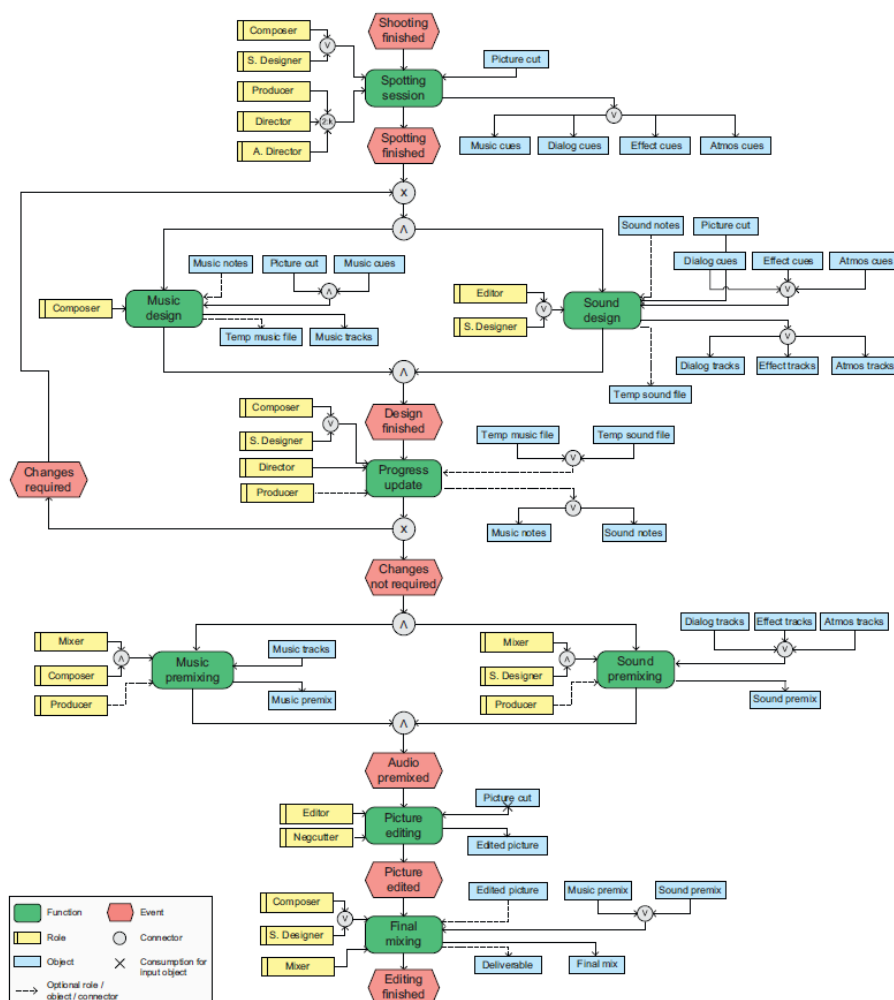


Figure 25: Reference process model of audio editing at AFTRS (Australian Film Television &amp; Radio School) [24]

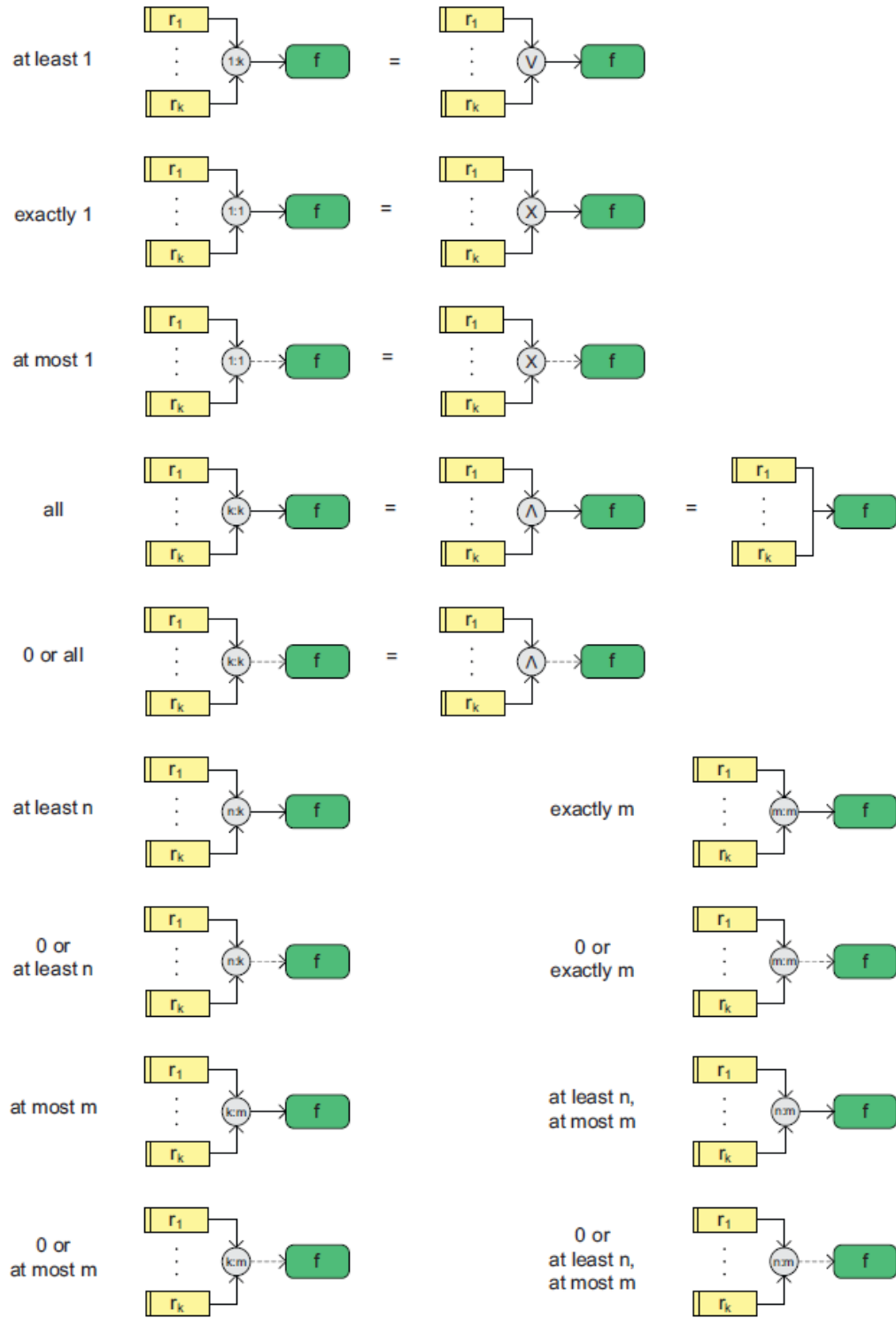


Figure 26: Range values for the range connectors [24]

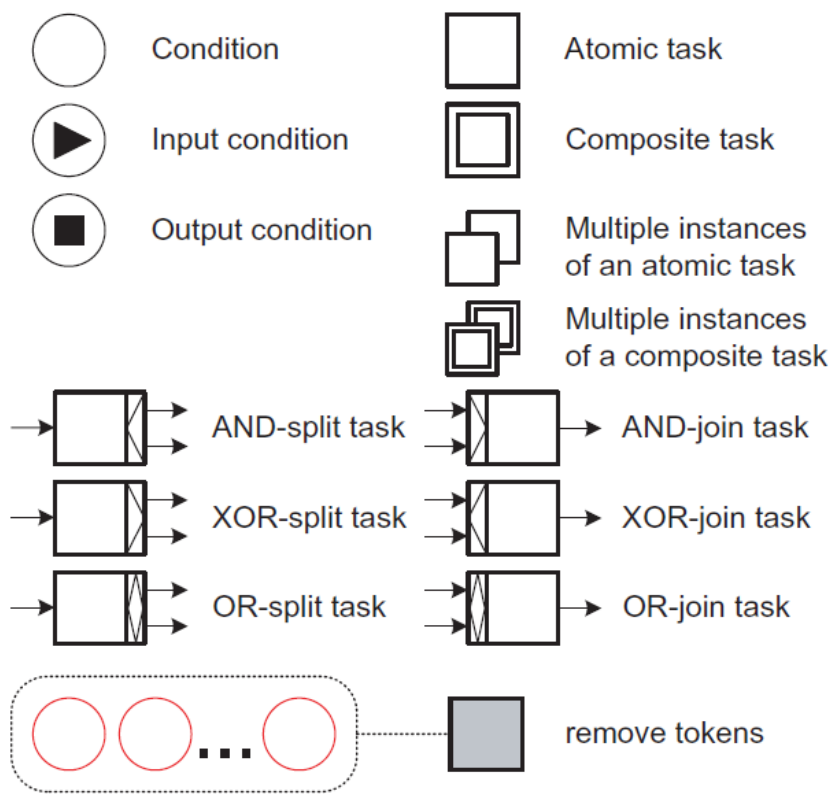


Figure 27: YAWL elements












1. INSERT-Operation	
Symbol	
Purpose	Addition of <i>process fragments</i> (A process fragment consists of at least one process element, e.g., activity nodes or control edges).
Parameters	<ul style="list-style-type: none"> <li>• Process fragment to be added with entries and exits marked by adjustment points</li> <li>• Target position of the process fragment within the base process, marked by adjustment points for entries and exits</li> <li>• Mapping between entries and exits of the added fragment to the target position within the base process (i.e., mapping of the respective adjustment points)</li> </ul>
2. DELETE-Operation	
Symbol	
Purpose	Removal of process elements
Parameters	<ul style="list-style-type: none"> <li>• Process fragment to be deleted with entries and exits marked by adjustment points</li> <li>• Alternatively: deleting single elements by referring to their ID</li> </ul>
3. MOVE-Operation	
Symbol	
Purpose	Change execution order of activities
Parameters	<ul style="list-style-type: none"> <li>• Process fragment to be moved with entries and exits marked by adjustment points</li> <li>• Target position of the process fragment marked by adjustment points</li> </ul>
4. MODIFY-Operation	
Symbol	
Purpose	Change attributes of process elements
Parameters	<ul style="list-style-type: none"> <li>• Element ID</li> <li>• Attribute name</li> <li>• Value to be assigned</li> </ul>

Figure 28: The Provop change operations [15]

Constraint Type	Visualization	Expression
Implication		$\neg(\text{Option}_x \wedge \neg \text{Option}_y)$
Mutual Exclusion		$\neg(\text{Option}_x \wedge \text{Option}_y)$
Order of Application		$\text{Option}_x \Rightarrow \text{Option}_y$
Hierarchy		$\neg(\text{Option}_x \wedge \neg \text{Option}_y) \wedge (\text{Option}_x \Rightarrow \text{Option}_y)$
at least n out of m*		$\min_n(\text{Option}_1, \dots, \text{Option}_m)$
at most n out of m*		$\max_n(\text{Option}_1, \dots, \text{Option}_m)$
exactly n out of m*		$\min \max_n(\text{Option}_1, \dots, \text{Option}_m)$

\*  $n \leq m, n \in \mathbb{N}_0, m \in \mathbb{N}$ 

Figure 29: Option constraints [15]

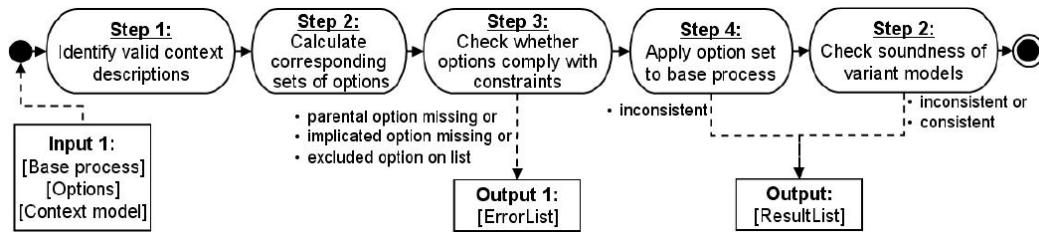


Figure 30: The Provop procedure for guaranteeing soundness [15]

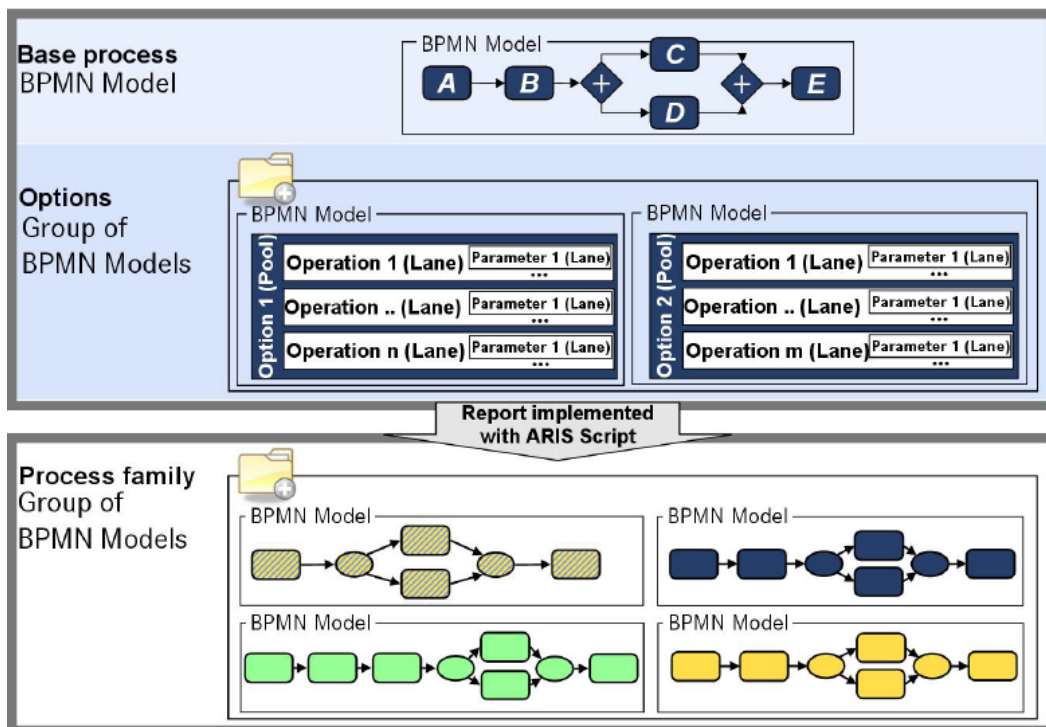


Figure 31: Architecture of the Provop prototype [15]

I-option	Comments
Group 1	
START	The execution of an activity is started.
DELAY/PROCEED	Starting execution of an activity is delayed/continued.
SKIP	The execution of a non-started activity is skipped.
Group 2	
PAUSE/CONTINUE	The execution of a started activity is paused/resumed.
CANCEL	The execution of a started activity is stopped and the activity is considered ended. Partial results from the execution of the activity remain.
PART-RESET	The execution of a started activity is stopped and the activity is put back in its ready state without undoing any of the work that has been performed.
PART-UNDO	The execution of a started activity is stopped, what has been done is undone, and the activity is put back in its ready state.
Group 3	
RESET	An activity that has ended is put back in its ready state. Results from previous execution are not undone.
UNDO	An activity that has ended is put back in its ready state, after the results from the previous execution are undone.

Figure 32: List of I-options [2]

Complex I-options	Constituent I-options	Comments
POSTPONE	DELAY+PROCEED	The execution of an activity is postponed.
RESTART	PART-RESET+START	A started activity is stopped and is started from the beginning.
PART-REDO	PART-UNDO+START	A started activity is stopped, undone, and started again.
TERMINATE	PART-UNDO+SKIP	A started activity is stopped and undone. The control flow is passed to the next activity.
RETRY	RESET+START	An ended activity is started from the beginning.
REDO	UNDO+START	An ended activity is undone and started again.

Figure 33: Sample list of complex I-options [2]

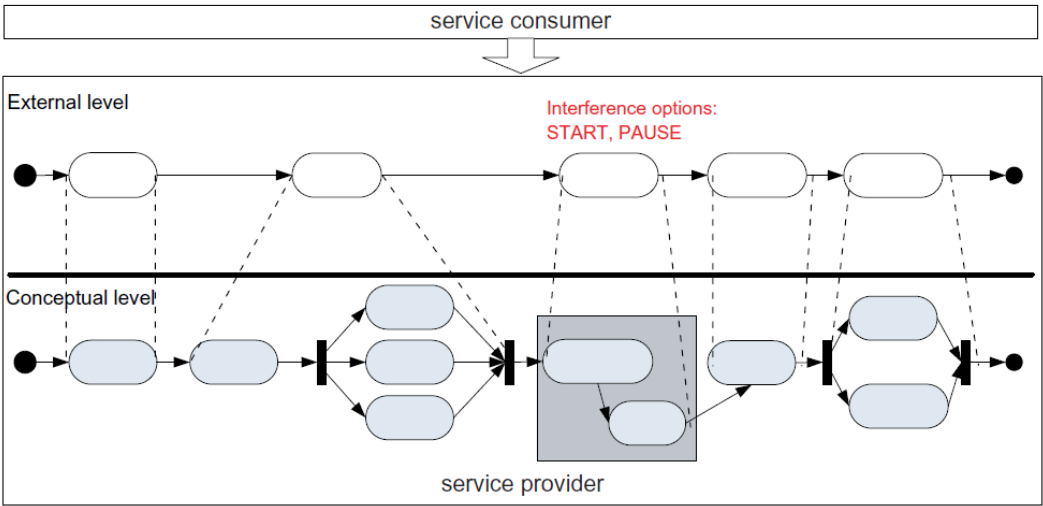


Figure 34: High-level architecture of S. Angelov's approach [2]

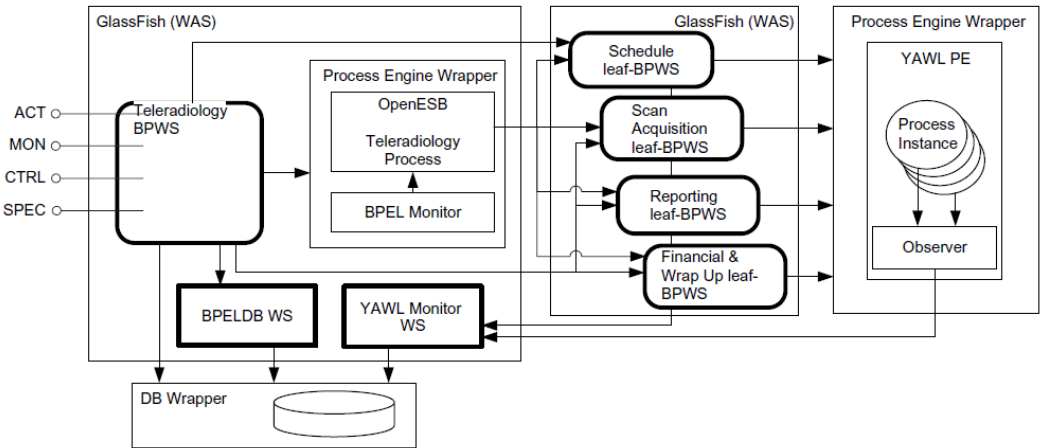


Figure 35: Implementation architecture of the PROXE System [2]

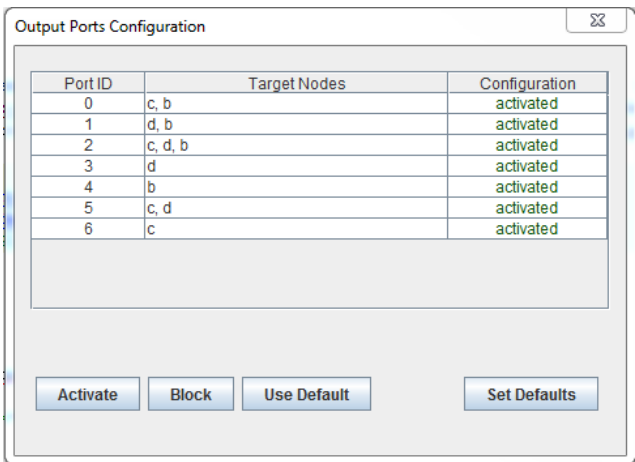
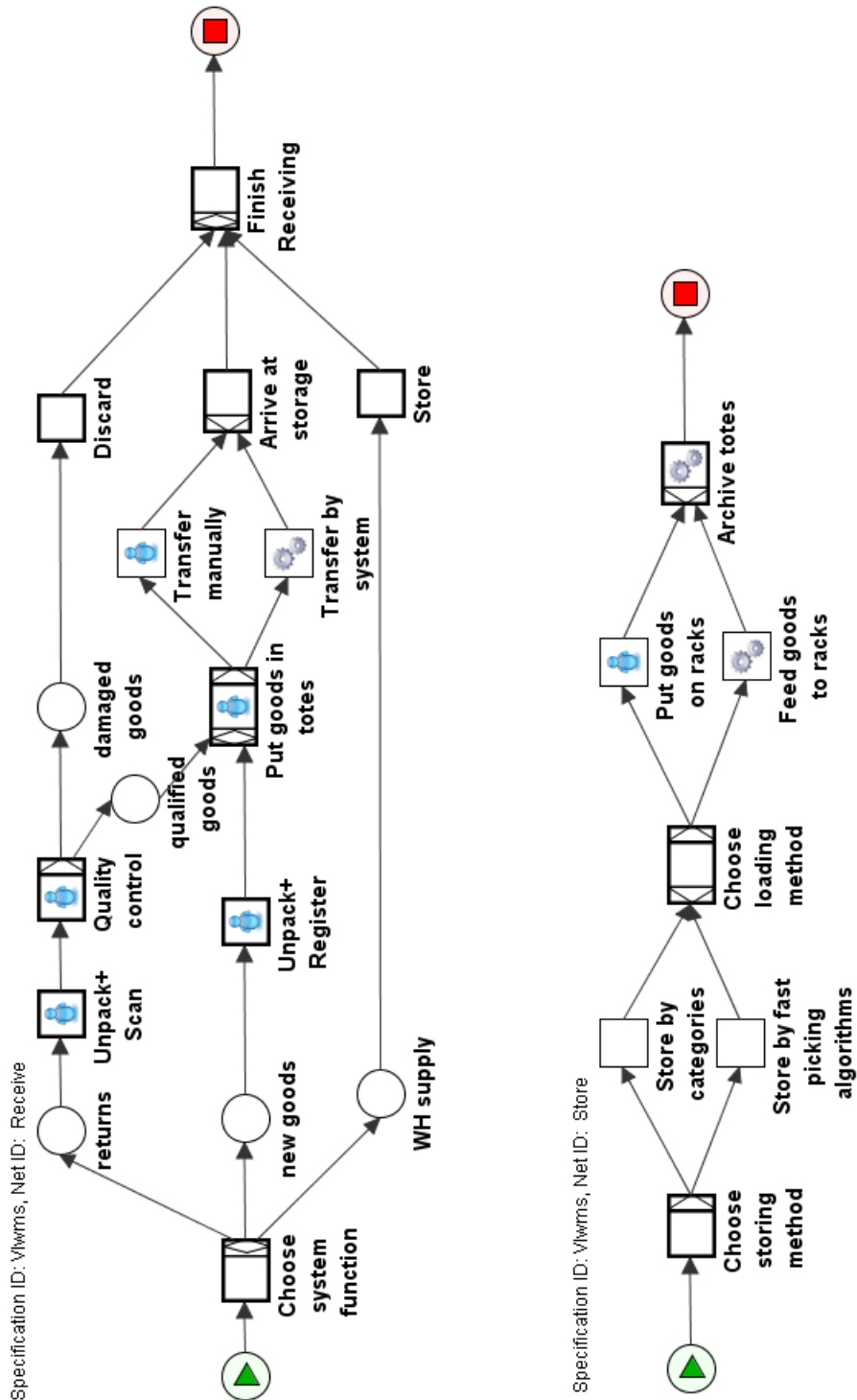


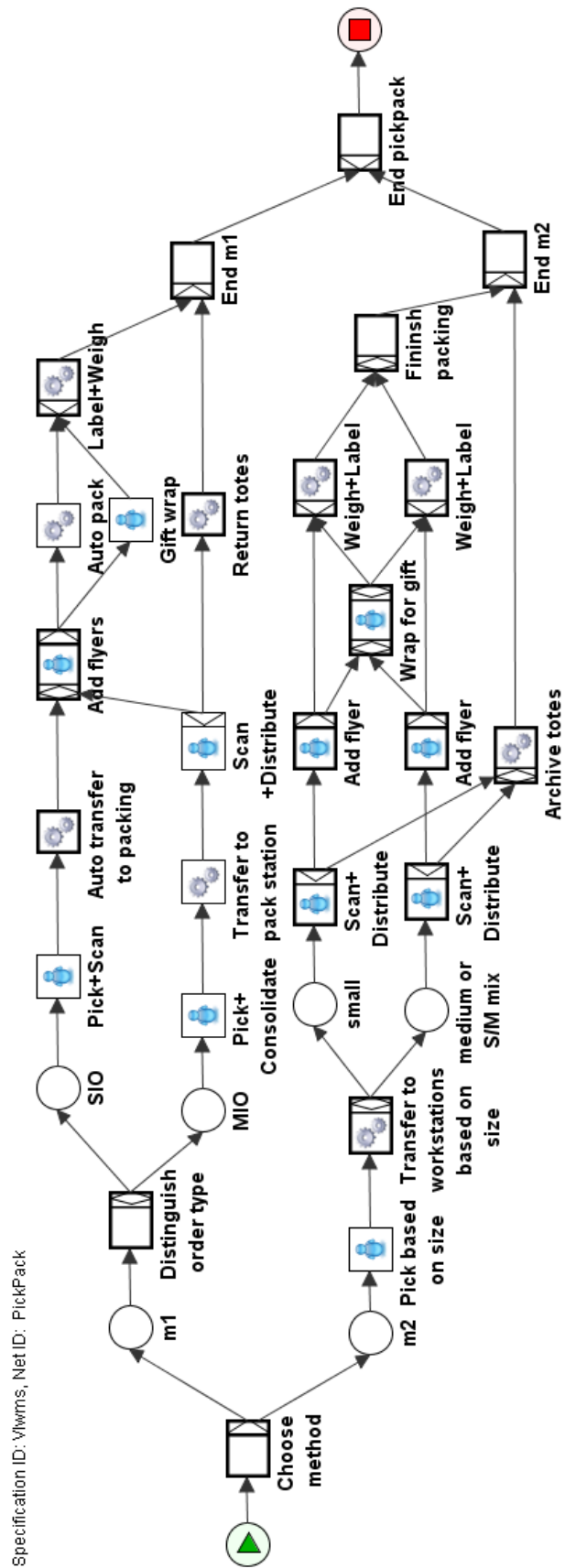
Figure 36: Output Ports Configuration in YAWL



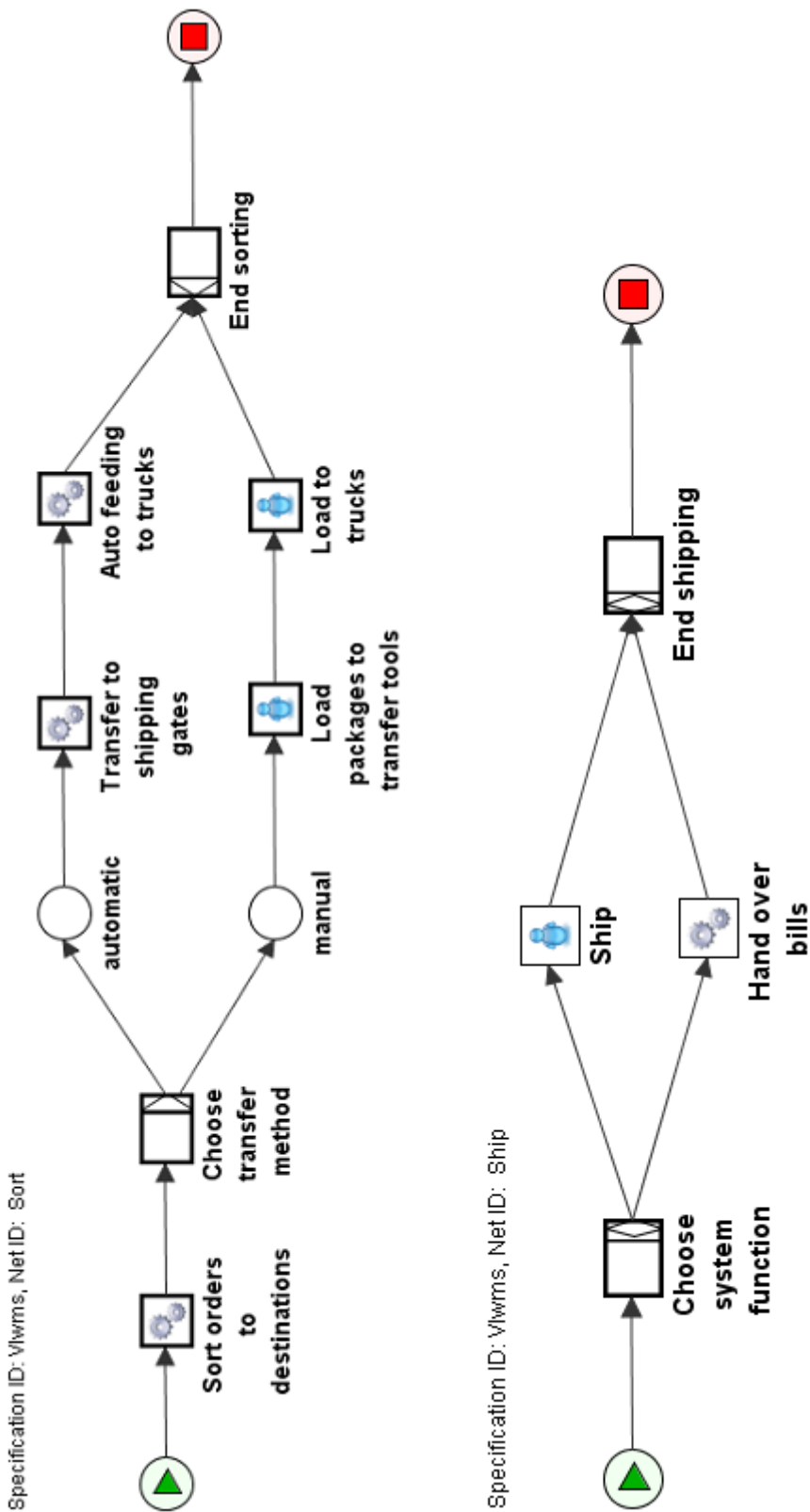
## WMS PROCESS MODELS



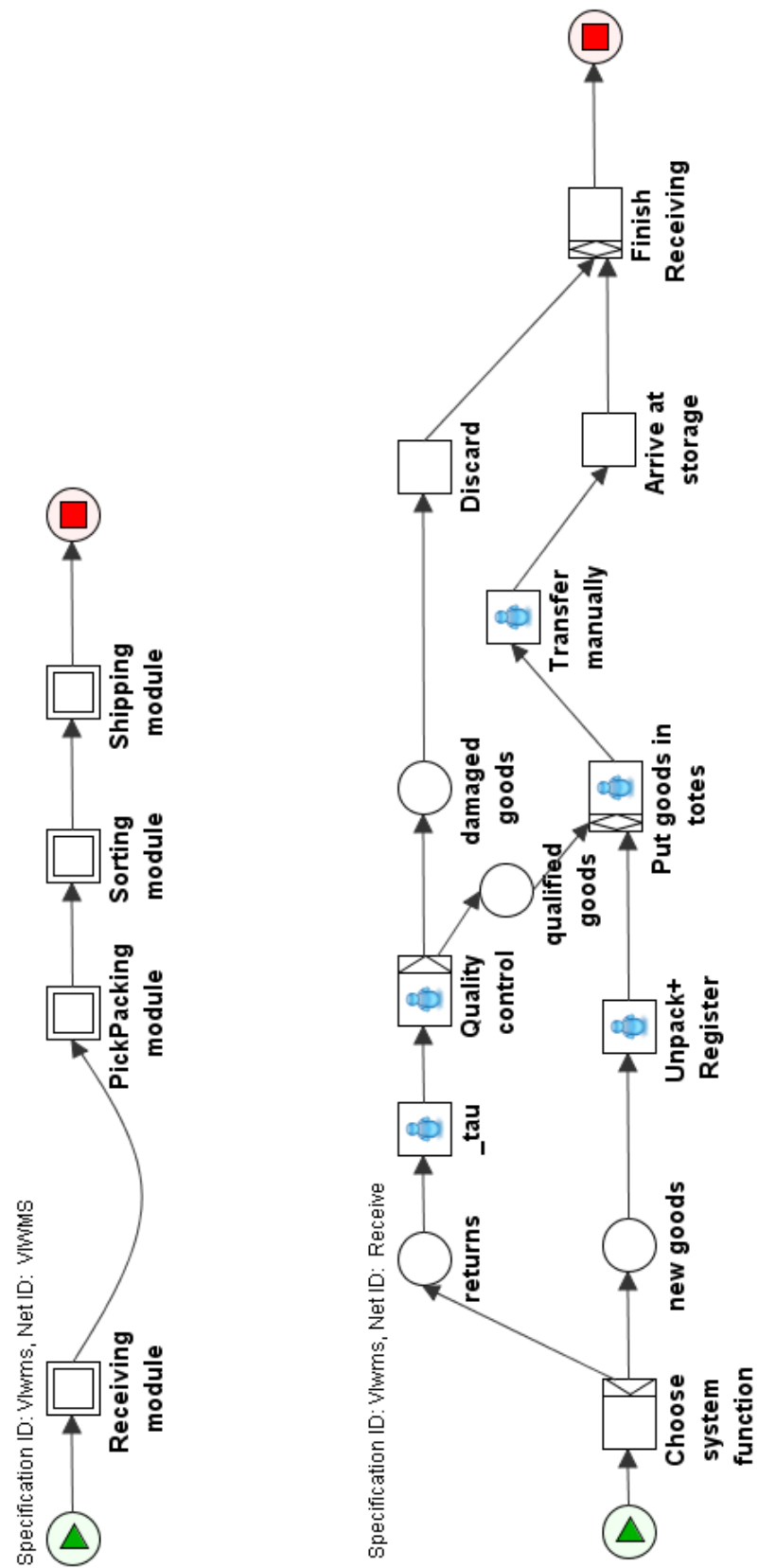
Configurable WMS - Receiving & Storing Modules



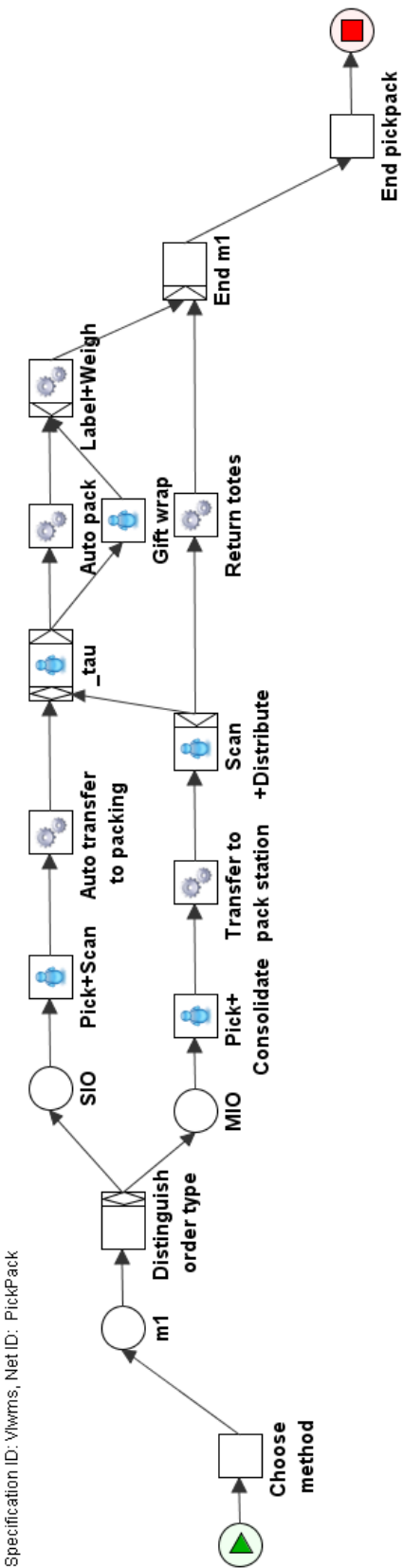
Configurable WMS - Picking&amp;Packing Module



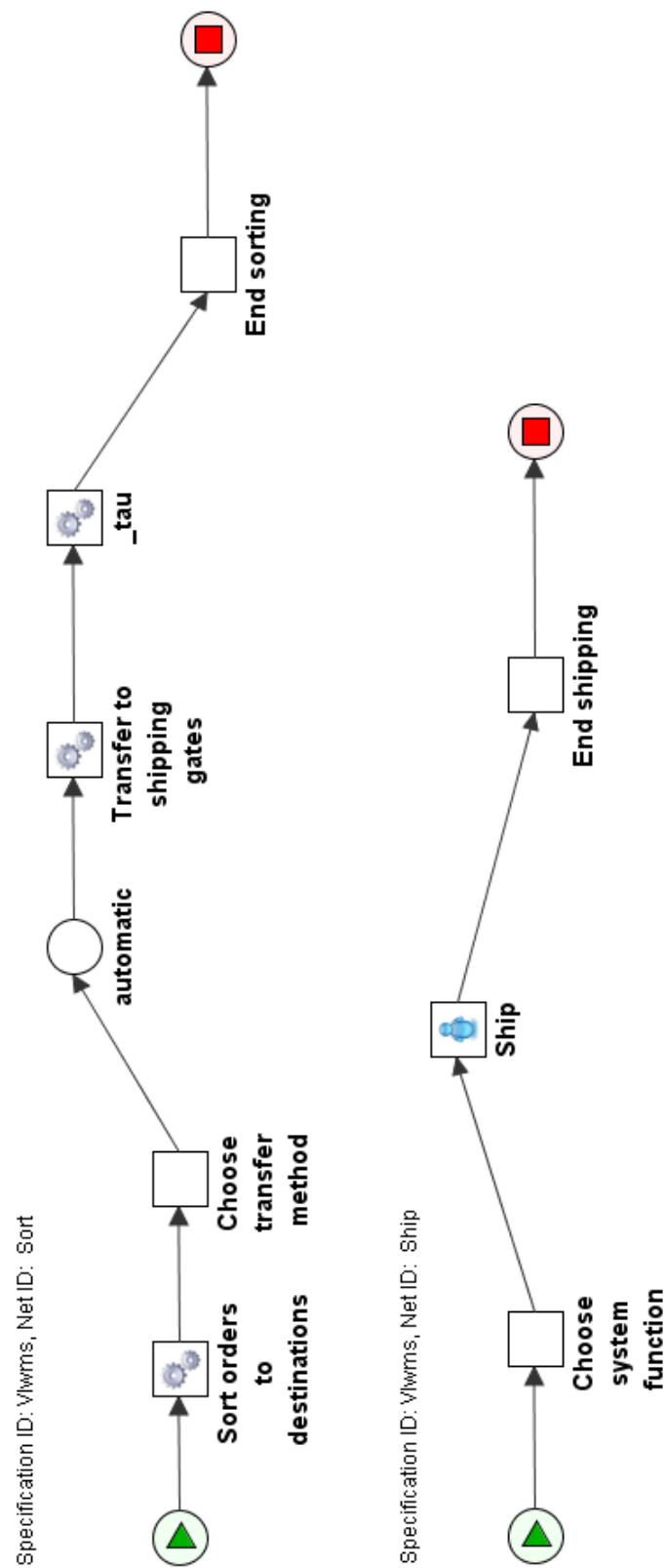
Configurable WMS - Sorting & Shipping Modules



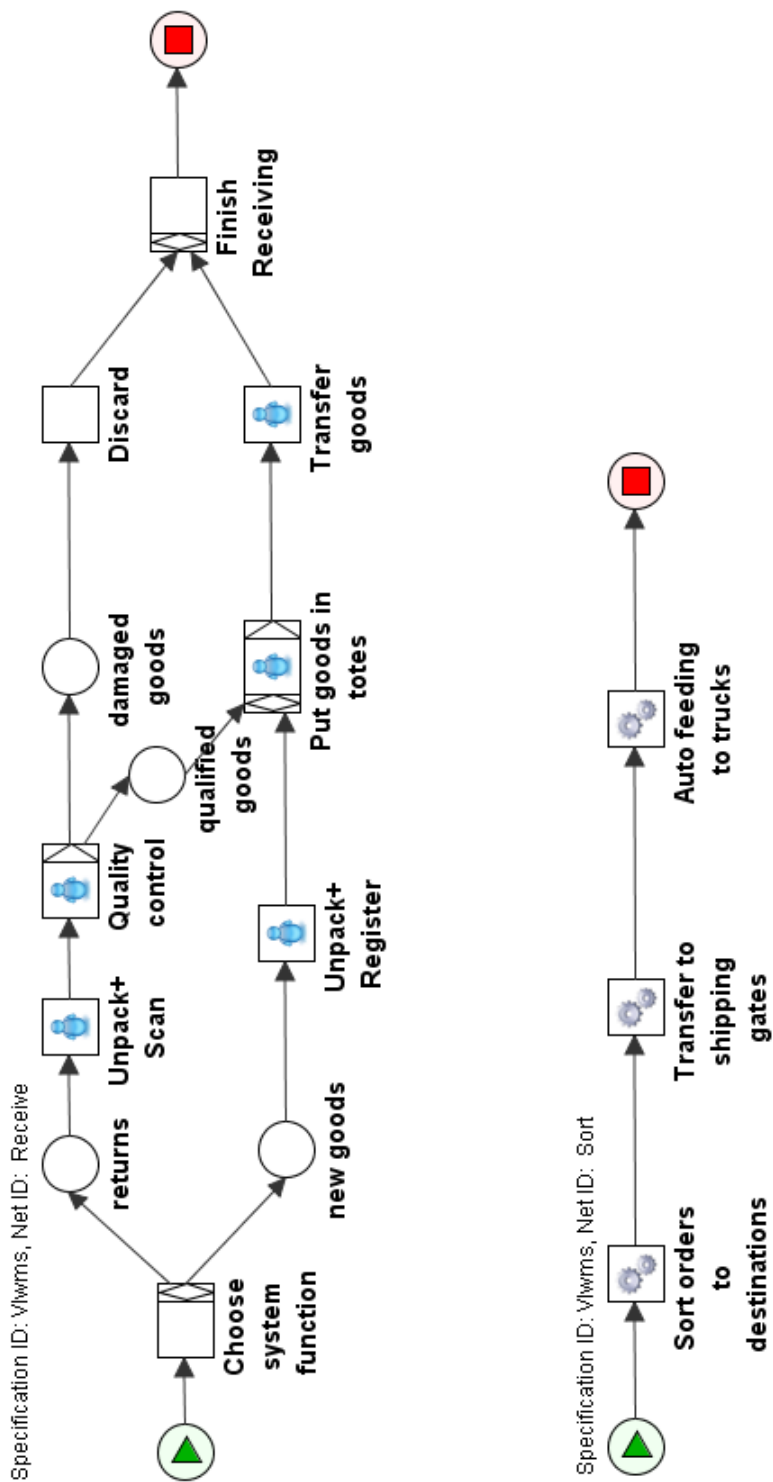
Configured WMS - Main net &amp; Receiving Module



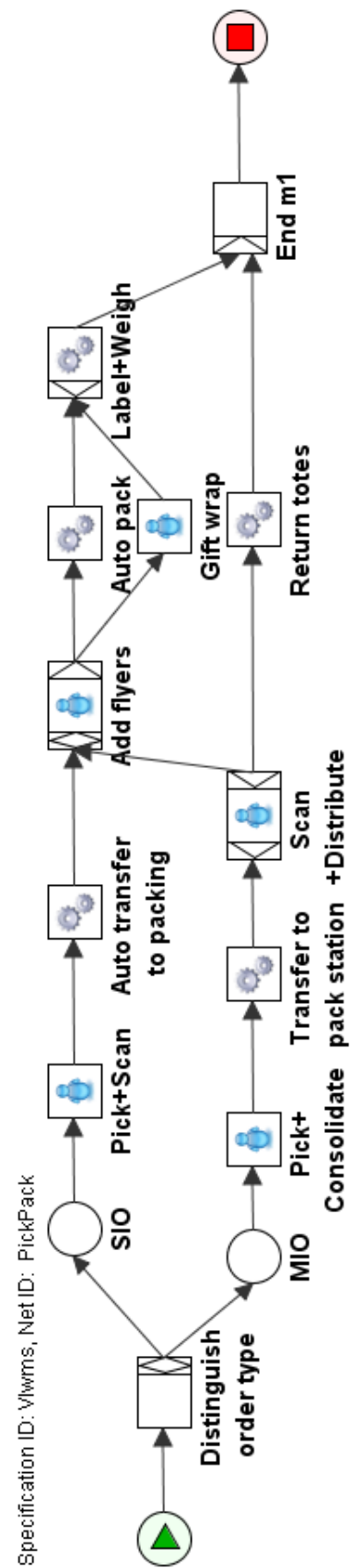
Configured WMS - Picking&Packing Module



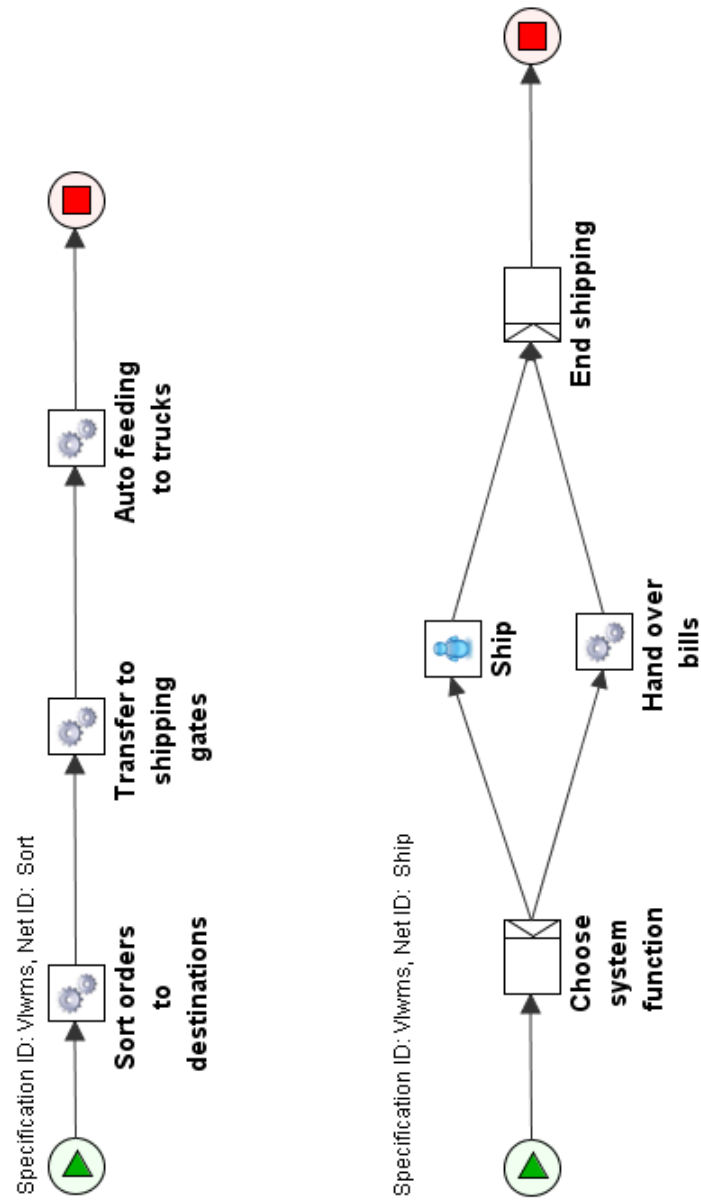
Configured WMS - Sorting &amp; Shipping Modules



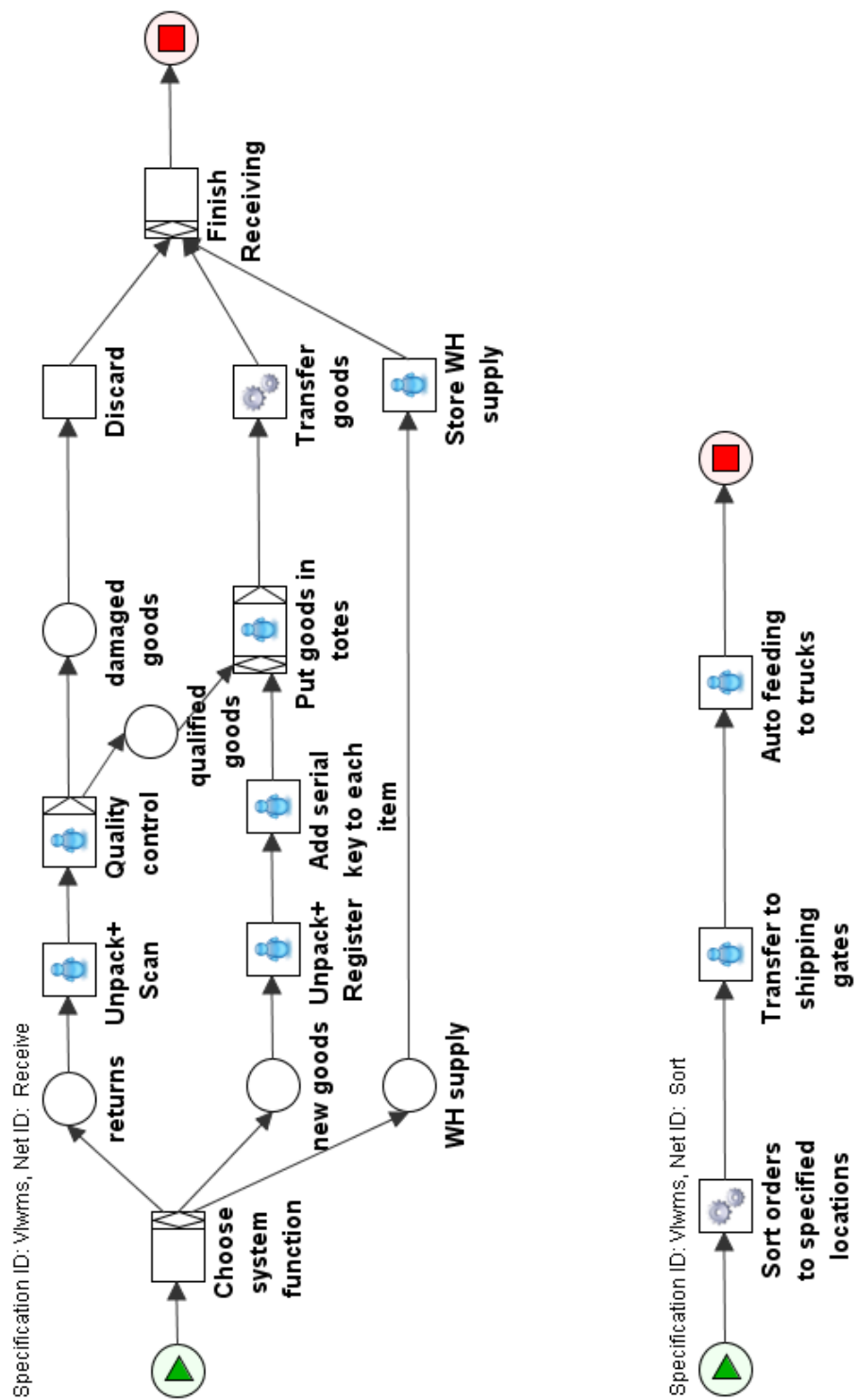
Base process - Receiving & Storing Modules



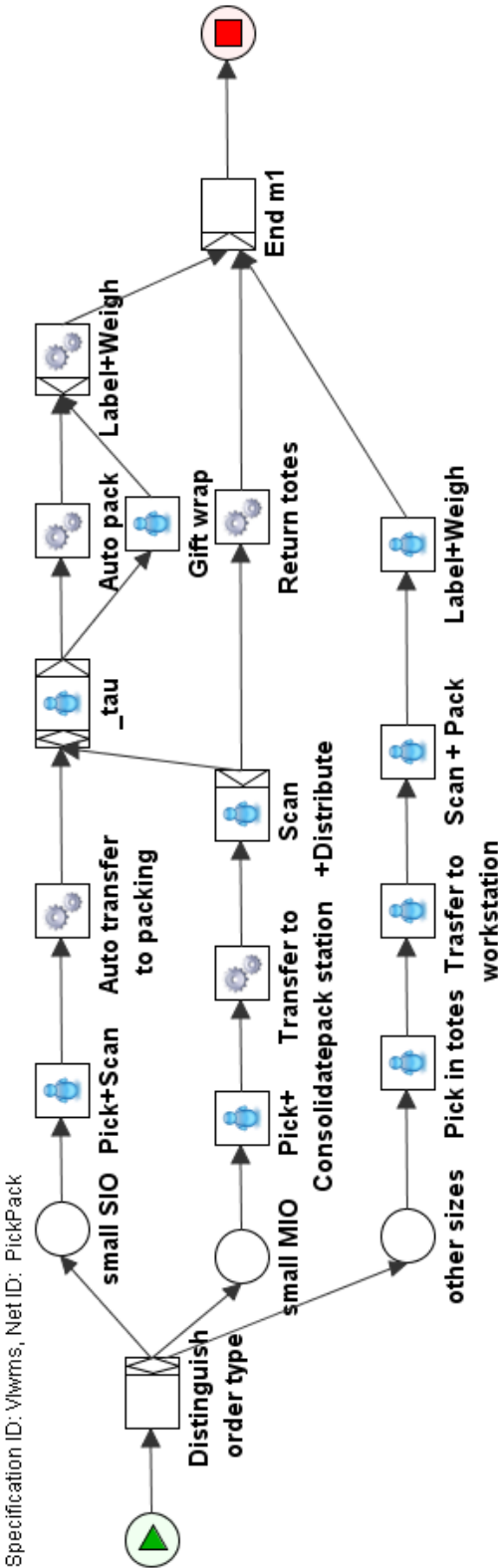
Base process - Picking&amp;Packing Module



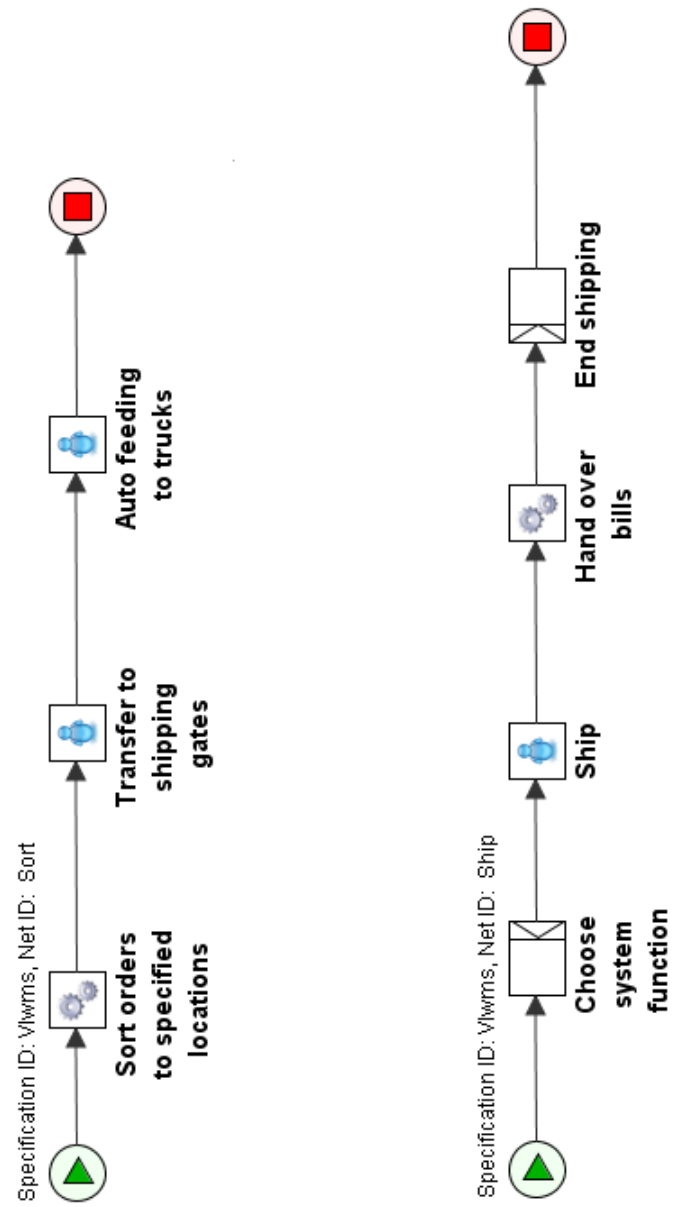
Base process - Sorting &amp; Shipping Modules



Customized Receiving &amp; Storing Modules



Customized Picking&Packing Module



Customized Sorting &amp; Shipping Modules

## EVALUATION SURVEY TEMPLATE

## EVALUATION SURVEY

### Business Process Configuration & Customization

Please complete the following Evaluation Survey based on the graduation project of Qian Li, which was carried out in the Systems Department, regarding Business Process Configuration and Customization for Warehouse Management System (WMS). After completion, please send your survey to [q.li@student.tue.nl](mailto:q.li@student.tue.nl). Thank you for your time.

Name:

Position:

Date:

1. Is Business Process Configuration an easier way for design compared to the current approach VI uses for designing WMS?

☐ Not at all    ☐ Not convenient    ☐ Neutral    ☐ Somewhat    ☐ Very

2. Which do you prefer, configuration or customization? Why?

☐ Configuration    ☐ Customization

3. To what extent do you think can Business Process Configuration benefit VI?

☐ Not at all    ☐ Not much    ☐ Neutral    ☐ Somewhat    ☐ Very

4. If it is beneficial to apply Business Process Configuration, what do you think are the benefits?

5. To what extent do you think can Business Process Customization benefit VI?

☐ Not at all    ☐ Not much    ☐ Neutral    ☐ Somewhat    ☐ Very

6. If it is beneficial to apply Business Process Customization, what do you think are the benefits?

7. In the presentation, C-YAWL is presented to configure the WMS process. Do you find it handy to operate?

☐ Not at all    ☐ Not convenient    ☐ Neutral    ☐ Somewhat handy    ☐ Very

8. What is your concern with Business Process Configuration? What do you think is the biggest challenge/drawback?

9. What is your concern with Business Process Customization? What do you think is the biggest challenge/drawback?

10. What issues/problems of designing WMS are still remained even if Business Process Configuration/Customization is applied?

11. Additional comments:

[Add your comments here.]

Thank you very much for taking time to complete this survey. Your feedback is valued and very much

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