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Model-based Analysis of Urban Community Logistics Courier Terminal System using Vacant Space

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Abstract

The growth of online market is accelerating due to the development of technology and the era of pandemic. In order to deliver the ordered product to customers courier service should be used. In addition, the courier logistics market is growing with the growth of the online market. With the growth of the logistics market, traffic and environmental problems are emerging as social issues. Logistics technology of urban community logistics courier terminal system utilizing vacant space in the city has been developed as a new alternative to environment and traffic problems by increasing logistics efficiency in the city area. In this study, we propose a concept of a system that performs operational concept definition and scenario analysis by applying model-based perspective analysis to urban community logistics courier terminal system under development. Through this study, we defined the operating concept of the urban community logistics courier terminal, which is the target of development, and defined the scenario for system operation by grasping the structure and function of the system and applied it to system development.

Keywords: *Model-based Systems Engineering, Community Logistics Courier Terminal, Urban Logistics*

1. Introduction

The growth of the online market due to the development of technology[1] and the arrival of the Pandemic era due to corona19 are accelerating the growth of the logistics market[2-3]. According to Statistics Korea, the

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logistics industry has increased about 2.4 times from 59.4 trillion won in 2001 to 146.9 trillion won in 2018 [4]. Sellers must use logistics transportation services through courier companies to deliver the products ordered to customers[5]. These delivery processes are mostly carried by cargo trucks using fossil fuels. According to the results of the Korea Transport Institute in 2016, the road transportation share rate was 91.1% based on tone and 96.2% based on transportation cost[6]. The increase in cargo vehicles for delivery due to the small quantity and the multi-frequency of cargo required for delivery caused traffic congestion costs of 46.7 trillion won(about 2.9% of GDP) in 2016[7]. The social costs such as air pollution, greenhouse gas, traffic accidents, road damage caused by exhaust gas discharged from the vehicle are also being generated. In accordance with the recent trend of global carboreduction and related regulations due to global warming[8], Korea is also responding to related matters through the 'Basic Roadmap Amendment for the National Greenhouse Gas Reduction Goals in 2030' for carbon reduction in 2018[9].

However, according to the increasing number of courier logistics, each courier company operates a logistics terminal individually in the city center, and traffic and environmental problems are increasing. In addition, the growth of the online market and the increase in early morning delivery due to changes in consumption trends are also affecting the explosive increase in the delivery service market. To cope with the rapid increase in logistics due to the rapidly changing consumption trend, we need to build a logistics center infrastructure in the city, but there is no appropriate alternative. To solve these problems, the technology to build a urban community logistics courier terminal system using vacant space in the city is being developed recently to improve traffic problems, environmental problems, and logistics efficiency due to the volume of courier goods. Development technology is a new concept of logistics system that utilizes vacant space in the city, and it is a system that integrates and processes cargoes of individual courier companies. To do this, accurate analysis of the system and definition of function and operational scenarios must be performed. This study conducted model-based analysis and system definition research for the urban community logistics courier terminal to be constructed and operated by utilizing vacant space in the city and derived the analysis results based on the model-based perspective of systems engineering. The definition and analysis results of the system concept stage derived from the study were proposed so that the system with improved operationality that meets the development goals can be constructed.

2. Definition of Problem

2.1 Development of the System for the Urban Community Logistics Courier Terminal

The community logistics courier terminal technology is a system that integrates the cargoes of individual courier companies that must be transported from vacant space in the city to their destination. The system of the urban community logistics courier terminal consists of systems that perform different roles such as Figure 1, so that the cargo can be recognized and classified and delivered to the destination. To build a community logistics courier terminal system, it is necessary to develop a courier terminal in a vacant space, a multi-chute for cargo classification, a cargo recognition system for invoice information recognition, and an operating system for terminal operation. Since the development technology handles several courier cargoes by utilizing vacant space in the city, it can help solve traffic congestion problems caused by cargo transportation by integrating distributed cargo travel routes by region. In addition, multifunctional multi-chute and cargo recognition technology can be used to classify large-capacity cargoes quickly and accurately, thereby contributing to improving logistics efficiency. And, it has the advantage of being able to deliver through connection with other eco-friendly mobile devices in the city.

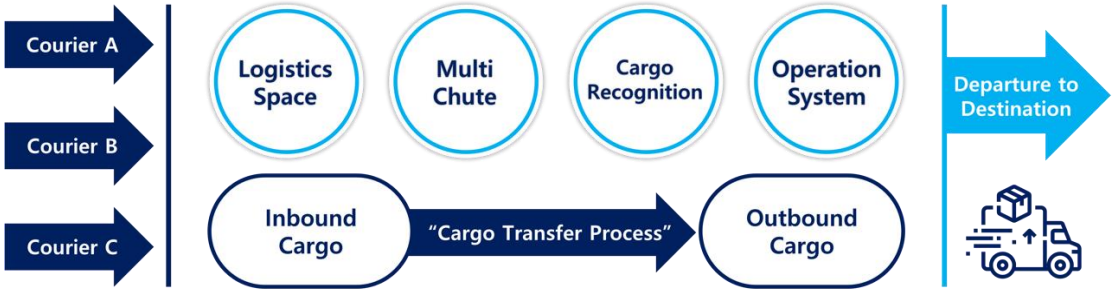

Figure 1. Community Logistics Courier Terminal System Composition

This city community logistics courier terminal technology can respond to the continuously changing market through the construction of optimized transportation system in the city. The target technology has several subsystems for performing functions in one system. To construct such a complex system, the approach, analysis, and definition of model-based systems engineering perspective for the target system should be preceded.

2.2 Model-based Systems Engineering Analysis

Modern systems are increasingly complex due to the development of technology and the segmentation of requirements, and large systems are increasing, so all activities that can affect the system should be analyzed. Model-based systems engineering can analyze systems with increasing complexity due to the development of technology and derive results considering essential aspects of the system. In addition, model-based system engineering analysis is a systems engineering technique that enables smooth undergrounding and communication among system-related stakeholder through Systems Modeling Language (SysML). SysML was defined and developed by the International Council on Systems Engineering(INCOSE) of the International System Engineering Association to efficiently support system modeling, such as Figure2[10]. The study of system engineering and model-based perspectives in relation to the analysis of the target system was also performed [11-12]. The SysML, which is used for model-based analysis, can be efficiently supported by implementing the system analysis results with visualization modeling[13]. Model-based analysis analyzes the target system based on structural and behavioral perspective and is suitable for system engineering analysis techniques that are excellent for analyzing complex systems such as community logistics courier terminal technology.

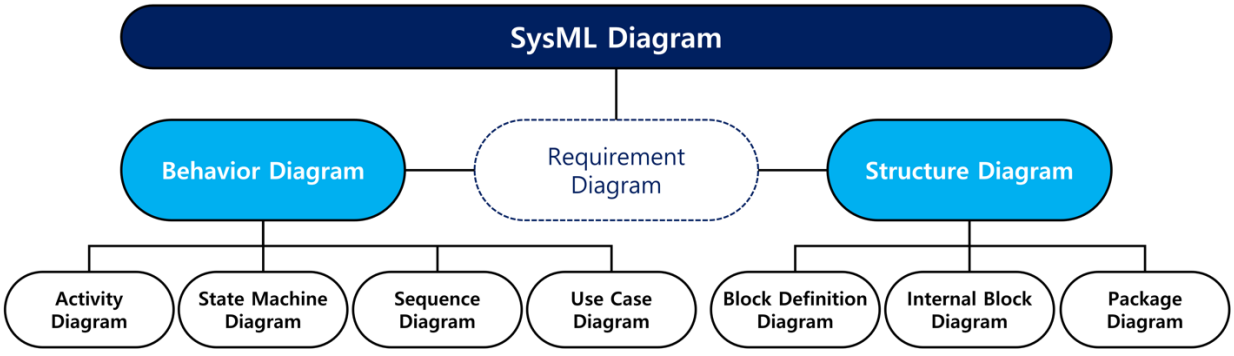

Figure 2. Systems Modeling Language

2.3 Related Research

A study on the construction of performance test requirements management system through model-based system engineering approach was carried out[14]. The previous studies suggested the results of the study on the necessity of system engineering approach and computer support tools to build a system, but they were

focused on the structural approach of the system to build a management model and secure traceability of the target system. A study on the integration of safety and reliability analysis based on model-based system engineering was also conducted [15-16]. The study confirmed that the use of model-based technology is suitable for system technology development, but it has limitations that it is focused on related methodology. The previous studies were conducted to utilize model-based system engineering analysis for system development. However, the previous studies have limitations that they focus on related methodology, improvement plan, and case study rather than focusing on the system model to be subjected.

2.4 Objective and Perspective

This study defines the concept of the system by conducting model-based analysis targeting the urban community logistics courier terminal using vacant space under development. Through this, the results of the study were suggested to be developed as a system that meets the purpose. The target system is to build and operate a courier terminal that jointly handles cargo in vacant space in the city, and it has the complexity of classifying and shipping several courier cargoes to destinations. Because many courier cargoes must be processed, there is a lot of throughputs, and it is necessary to develop technology to accurately ship them to the destination. To analyze such a system, research applying the model-based systems engineering perspective should be performed as in previous studies. For this purpose, this study conducted a model-based structural and behavioral analysis of the target system, identified components to control the complexity of the system, defined related matters, and conducted a study to enhance the awareness and understanding of the system and to understand the relationship between the subsystems. The results of the study were suggested and reflected in the system to help develop the system that fits the purpose.

The composition of this study is like Figure 3. Chapter 1 deals with the background of the study, the necessity of technology development, and the goals. In chapter 2, the precedent studies related to model-based analysis were identified, and the definition of the problem, the scope of the study, and the method of study were defined. In chapter 3, we conducted model-based perspective analysis of system concept and constructed the system operational concept definition, structure and function definition and operation scenario to derive the results. In chapter 4, the results of the study were summarized.

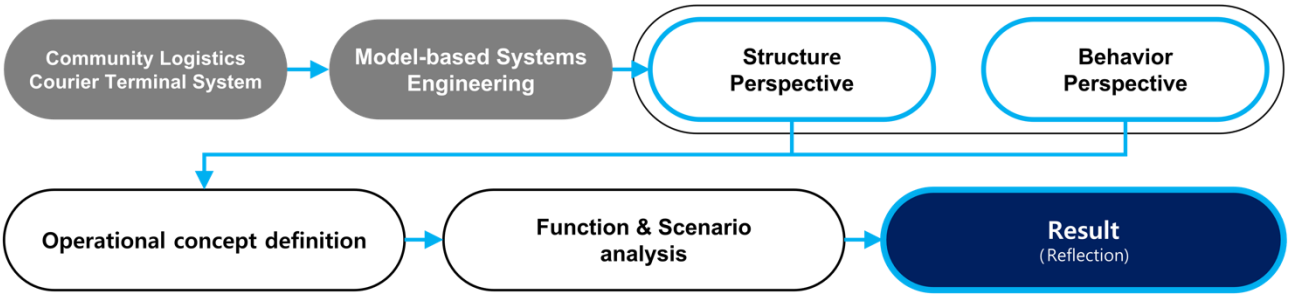

Figure 3. Objective and Perspective

3. System Analysis of Model-based Perspectives

3.1 System Analysis of Model-based Structural Perspectives

The development of the technology of the urban community logistics courier terminal is a system that classifies the cargoes and ship them to the destination by utilizing the vacant space in the city. For the analysis of the structural perspective of the target system, the operational concept of the entire system was defined as Figure 4. As Figure 4 the target system operates the courier terminal operated by the exiting individual courier companies jointly, so the cargo to be shipped to the destination should be processed quickly and accurately. The cargo loaded in the terminal consists of a process of recognizing destination information through a scanner and transmitting the destination dock through an operating system and multi-suit equipment. To carry cargo transported from individual couriers to the terminal, a dock must be constructed that allows access to the cargo

truck. Since the cargo in stock must be classified collectively through multi chute, a conveyor must be built to transport cargo to each cargo dock. To this end, multi chute should be designed and developed to transport cargoes in each dock immediately. In addition, for the recognition and classification of the cargo, the cargo information recognition system through the scanner should be established, and the operating system for the overall system operation of the courier terminal should be developed. For the cargo classified by destination to be shipped, a cargo truck for cargo shipment or a dock capable of accessing small mobile means must be constructed.

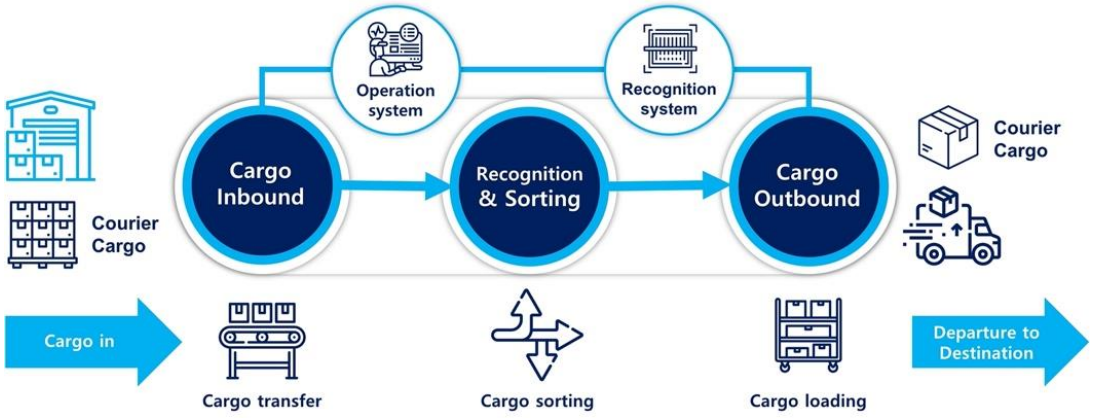

Figure 4. Operational Concept of Systems

To recognize and classify the cargo in the urban community logistics courier terminal system and to deliver it to the destination, it is necessary to operate the entire system stably and smoothly through the linkage between subsystems. Through the definition of operational concept, structural analysis of the target system was performed, and block definition diagram was derived like Figure 5. The system was structurally defined through the block definition diagram of Figure 5. The first definition of the target system is the vacant logistics space for terminal construction and operation. The second is defined as a multi chute for transport and classification of cargo; the third is a cargo recognition system for information recognition of cargo. Fourth, the operation system plays a role of operating the overall contents of the terminal.

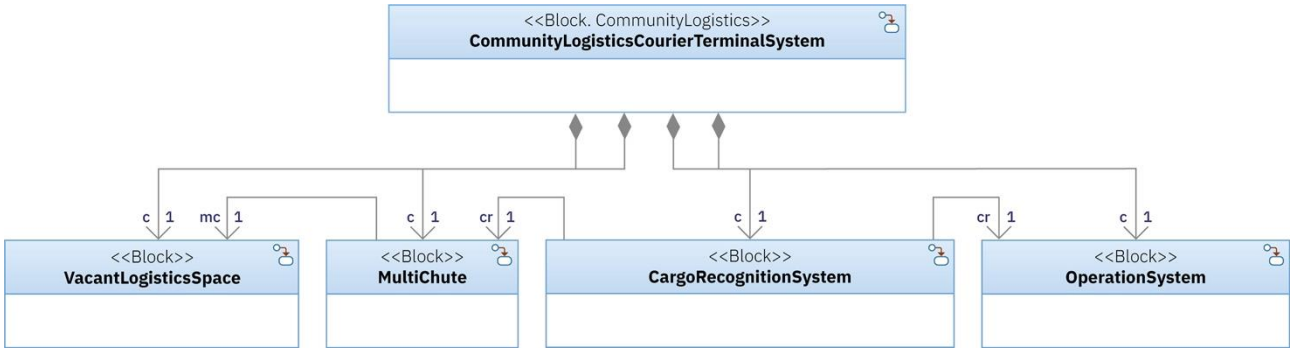

Figure 5. Block Definition Diagram

The interface between devices was identified through the derived results and the entire system was defined as Figure 6. Figure 6 is a hierarchical visualization of the analyzed results from a structural perspective. Based on the results derived from SysML, the subsystems of the target system are defined as logistics space, multi chute, cargo recognition system, and operation system. In addition to the physical system, the operating system related to the operation was identified. The relationship between the operating system and the system for cargo recognition was defined and divided, and the relationship between the operating system and the multi chute was defined.

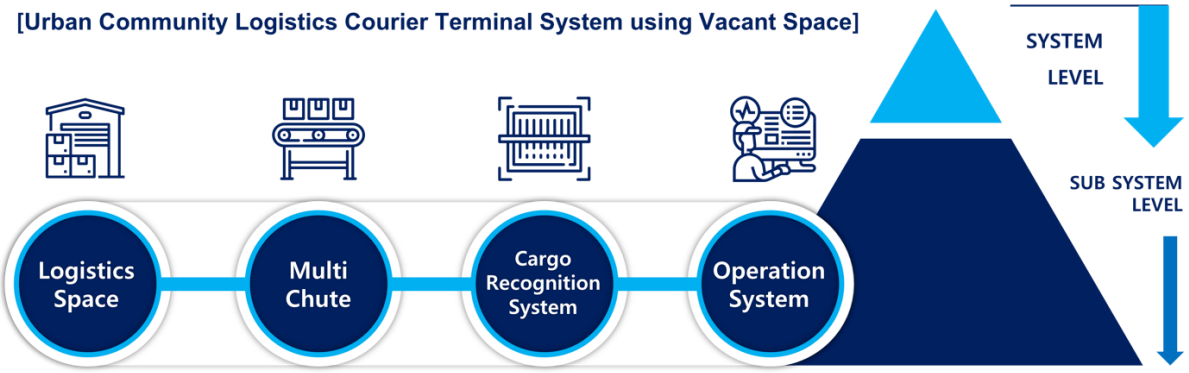

Figure 6. System Hierarchy Structure

3.2 System Analysis of Model-based Behavioral Perspectives

The structure of the system is defined like Table 1 through the structural perspective of urban community logistics courier technology development using vacant space. Based on performed a dynamic perspective analysis of the target system and defined the function and scenario of the system. The sysrem function of the urban community logistics coiurier terminal is cargo departure to destination, and each sub system function is as follows. Logistics space using vacant space performs the cargo inbound & outbound process. The multi chute system performs the cargo transfer and sorting. The cargo recognition system is proceeding the cargo information recognition. The operation system performs the terminal operation and cargo control.

Table 1. Function of System & Subsystem

Level	Division	Function
System	Urban community logistics courier terminal system using vacant space	Cargo departure to destination
Sub-system	Logistics space using vacant space	Cargo inbound & outbound process
	Multi chute system	Cargo transfer & sorting
	Cargo recognition system	Cargo information recognition
	Operation system	Terminal operation & cargo control

Based on this, the scenario of the entire system was identified. The scenario stage was composed and defined as the process of recognition, transfer, classification, and shipment, starting with cargo inbound to the terminal. The operational configuration based on the defined system concept was derived as Figure 7 expressed through activity diagram. The conveyor boarding process for the multi chute transfer of cargo operates starting with the cargo of the individual courier company being stocked to the courier terminal. It is acknowledged through the cargo recognition system and the information of the cargoes transferred to is transmitted in the operating system. The operating system transmits the related information with the multi chute so that cargo be transferred to dock based on the acknowledged information. When the cargo is transferred through the multi chute, the vehicle dispatch for the cargo shipment is completed. And it is loaded after the inspection of the worker, and it is shipped to the destination location. It is loaded in the small cargo truck or the environment-friendly transfer method and cargoes in which inspection is completed are delivered to the destination location.

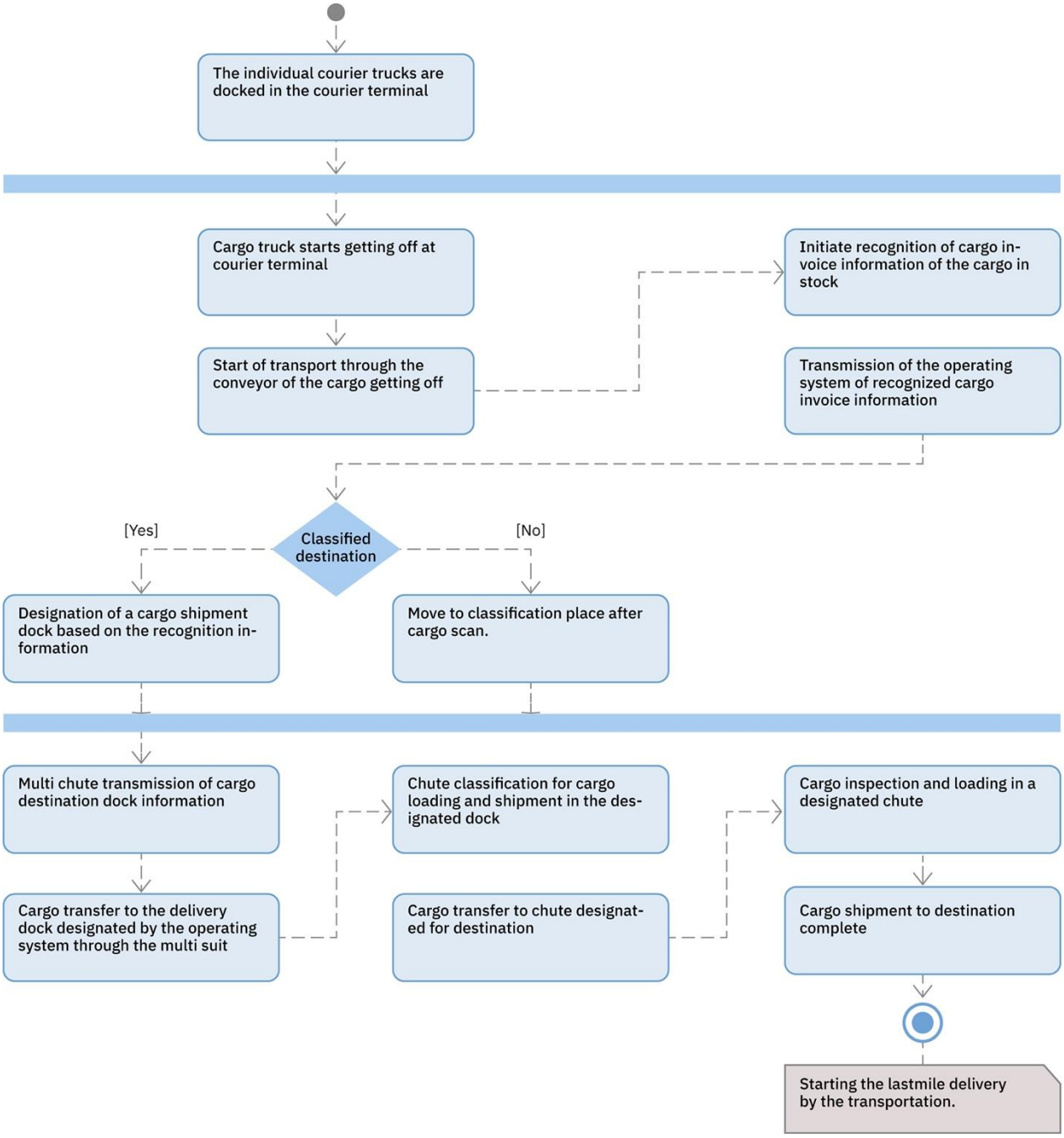

Figure 7. Activity Diagram

The whole scenario and detailed scenario of the system concept level were defined through the behavior p erspective analysis, and the detailed scenario of the target system is like Table 2. The scenarios were defined based on five steps: cargo in, cargo recognition and operation, cargo transfer, cargo sorting, and cargo out. Each step was configured for the function the system was aiming for, and information about where the scenario was performed was also defined. Based on the results derived from the model-based structural and behavioral perspectives, the definition and composition of the target system were clearly reflected in the system development.

Table 2. Model-based System's Scenario

Level	No	Scenario	Location
1. Cargo in	1-1	The individual courier trucks are docked at the courier terminal	Inbound Dock
	1-2	Cargo truck starts getting off at courier terminal	
	1-3	Start of transport through the conveyor of the cargo getting off	
2. Cargo recognition and operation	2-1	Initiate recognition of cargo invoice information of the cargo in stock	Cargo recognition system
	2-2	Transmission of the Operating System of Recognized Cargo Invoice Information	
	2-3	Designation of a cargo shipment dock based on the recognition information	Operation system
	2-4	Multi chute Transmission of cargo Destination Dock Information	
3. Cargo transfer	3-1	Cargo Transfer to Shipment Docks Designated by Operating Systems through Multi chute	Multi chute
4. Cargo sorting	4-1	Chute Classification for cargo Loading and Shipment in the Designated Dock	Multi chute
	4-2	Cargo Transfer to chute Designated for Destination	
5. Cargo out	5-1	Cargo inspection and loading in a designated chute	Outbound dock
	5-2	Cargo shipment to destination complete	

4. Conclusion

This study conducted a model-based analysis of the technology development of the community logistics courier terminal that classifies and delivers cargo using vacant space in the city and conducted a study to derive the results and apply them to the system under development. We applied the structural and behavioral perspectives of model-based analysis to analyze and accurately understand the target system through the study and performed the system's operational concept definition, structure definition, function identification and scenario derivation. The target system is a new concept system that uses vacant space to receive and classify cargo from individual courier companies and ship them to destinations. It consists of several subsystems. To achieve the function implementation and purpose that the whole system aims at, clear definitions of the system must be given priority. We tried to contribute to the construction of more reliable system by reflecting the model-based analysis results proposed in the study in the system development. In the future, we will continue to carry out more detailed analysis research based on additional definitions and system confirmation specifications while developing detailed systems for the target system.

Acknowledgement

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