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Diagramming development for a base camp and staging area in a humanitarian logistics base airport

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Abstract

Purpose – The purpose of this paper is to develop a method for diagramming a base camp or space for emergency workers and a staging area to be used during sorting, storing, loading, and unloading of relief goods in a humanitarian logistics base airport.

Design/methodology/approach – A method is developed based on a synthesis of the relevant literature and current practices of airports. This provides a means for estimating the area required for each facility and visualizes the layout of the base through an adjacency diagram and a bubble diagram. The method is applied to the Shizuoka Airport in Japan as a case study.

Findings – The proposed method can be used to determine the approximate size and layout of a humanitarian logistics base in an airport based on the affected population and the number of emergency workers.

Research limitations/implications – Airport operation regulations and mathematical models from architectural planning need to be reflected further.

Practical implications – The method provides potential operational improvements for policies and standards for airport operations and enables government officials and humanitarian logistics organizations to identify concerns in facilitating and managing constraints in existing airports.

Originality/value – This study addresses the detailed phases in a diagramming for a humanitarian logistics base airport by integrating an architectural approach and airport disaster management. The results highlight the importance of managing the flexible use of space to improve effective humanitarian logistics.

Keywords Space planning, Disaster response, Base camp, Humanitarian logistics base, Staging area

Paper type Research paper

1. Introduction

Air transport is critical in the immediate disaster response phase. It is highlighted as an alternative to road and rail transportation particularly when ground transportation has been paralyzed in the aftermath of events such as earthquakes or tornadoes. In the immediate response phase (the first 72 hour after a disaster), emergency medical care is extremely dependent on air travel. An airport (node) in the impacted area will become a base supporting various humanitarian activities. Additionally, air routes (links) enable delivery and recovery from the affected zone, carrying evacuees, aid goods, and other cargo.

Airports are often referred to as disaster response bases or humanitarian logistics bases in the immediate phase of a disaster response. They provide critical disaster response functions as well as facilities such as staging areas, logistics centers, base camps, and medical treatment areas, ensuring the effective flow of commodities, and personnel. However, the use of the available space in airports for post-disaster activities faces limitations due to insufficient parking space for aircraft, limited space for the temporary storage of fuel drums, and

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shortages in the prepared space for temporary lighting facilities, storerooms for storing relief goods, and space for setting up staging care units (Hanaoka *et al.*, 2013).

The importance of disaster response management at the airport has long been recognized, but the formulation of guidelines for the development of disaster preparedness plans related to large-scale catastrophes was hampered after the Great East Japan earthquake (Holguín-Veras *et al.*, 2012). Kapucu *et al.* (2007) focused on the pre-selection and layout of a staging area and mentioned that there are no officially documented guidelines for emergency management planning that address the selection or planning of a staging area. However, their study did not consider the internal configuration process and other critical facilities of a humanitarian logistics base. Current airport disaster management planning practice does not address the details of operating in the limited spaces in airports, such as how to assign the limited available space for various purposes. In this study, we argue that airports need to prepare for such space requirements and flexible operation in advance to ensure efficient and effective humanitarian logistics in airports. We recommend the use of space planning models for airports that can be employed in response to disasters and especially focus on diagramming in the planning models. The proposed method was devised to aid in making tactical decisions related to space utilization in airports in conjunction with specified logical procedures to be implemented in emergencies. The main contribution of this work is the development of an integrated framework that combines existing models and methodologies for application in immediate disaster response operations at airports.

The purpose of this study is to develop a method for diagramming a base camp and staging area as a humanitarian logistics base airport. The method enables the planner to estimate the required space and configure a layout for a humanitarian logistics base airport in an immediate disaster response situation. To achieve this objective, the space limitation issues in an airport were addressed in this study in the context of post-disaster relief activities and the need for effective decision making related to diagramming for use of an airport as a humanitarian logistics base. The diagramming method developed in this study is easy to comprehend and outlines the flow of goods and logistics for the benefit of airport operators, humanitarian aid organizations, government officials, and related stakeholders in responding to disasters.

The next section gives a summary the related literature on the operation of airports as disaster response bases. The proposed research method of this study is presented in Section 3. Section 4 presents the proposed layout for a humanitarian logistics base at the Shizuoka Airport in Japan, which is used as a case study; the results for the estimation of the required area, and the corresponding diagrams of a base camp and staging area. Finally, Section 5 presents the conclusions drawn from the research along with a discussion of the limitations of the study and the directions for future research.

2. Literature review

2.1 Airport as a humanitarian logistics base

Previous natural disasters highlighted the importance of utilizing airports in the immediate disaster response phase. In case of Hurricane Katrina in 2005, the roof and hangars of the New Orleans Airport experienced little damage. The airport was therefore actively used in military, humanitarian, and rescue operations. Because there were more than 27,000 patients in the airport, the terminal served as a staging area and a shelter for more than a week after the hurricane struck the region (Perkins, 2015). Conversely, there was a single runway in the Port-au-Prince airport at the time of the 2010 Haiti Earthquake, resulting in enormous congestion and hindering effective utilization of the airport (Pasztor *et al.*, 2010). The airport failed to handle the overwhelming flow of items, people, and aircraft that concentrated there in the immediate disaster response phase. Still, response efforts continued to utilized the airport as a point of entry to the country. A similar situation occurred in the 2015 Nepal Earthquake when the World Food Program established a staging area for goods and medical evacuation in the Kathmandu Airport, using it as a disaster response base immediately after the quake.

Current practices related to the utilization of airports as humanitarian logistics bases are summarized in Table I. Smith (2007, 2010) examined the role of airports and coordination among regional airports during disasters. He investigated actual response activities and measures undertaken during previous disasters based on case studies. In the USA, airport guidelines for preparing for emergencies and mutual aid agreements between nearby regional airports, such as WESTDOG and SEADOG (TRB, 2012), have been proposed. The Regional Logistics Hub for Humanitarian Assistance in Panama is one of the practical plans initiated by the International Federation of the Red Cross (IFRC) and Red Crescent Societies. The IFRC placed its regional logistics unit in Panama to make it possible to respond to disasters quickly, especially during hurricane season. It is designated to cover the disasters in Latin America and the Caribbean (Martinez *et al.*, 2010). The hub incorporates an airport and several international humanitarian organizations that utilize the warehouses, open space, staging area, aprons, and helipads (UNOPS, 2012).

The logistics company DHL and the United Nations Development Programme (UNDP) developed a training program for airports in developing countries to help them prepare for emergencies. The program has been presented since 2009 (Deutsche Post DHL, 2010). A pilot program was initiated in two airports: Makassar and Palu in Indonesia. In Japan, a similar approach has been initiated by the Japanese government to assign airports for use as humanitarian logistics bases.

As part of disaster management planning, the Airport-to-Airport Mutual Aid Program, which was initiated with the voluntary assistance from airports in the aftermath of major natural disasters in the USA, was reviewed for this study. The Airport-to-Airport Mutual Aid

	Location	Coverage	Role	Features
Regional Logistics Hub for Humanitarian Assistance in Panama (2011)	Panama	International	Supports humanitarian logistics activities Warehouse Staging area Facilitates cooperation among international relief organizations	Humanitarian logistics hub is planned as part of the airport plan
Get Airports Ready for Disaster (2009)	Pilot program: Indonesia (Makassar and Palu)	Domestic	Prepare airports to review capabilities and capacities Support humanitarian logistics activities Train local people Build a cooperative structure for disaster response	Training program for airports led by DHL and UNDP in 2009
Airport-to-Airport Mutual Aid Program: SEADOG and WESTDOG (2012)	USA	Domestic	Regional assistance between airports Assist airport's functionality during disasters, emergencies, and non-disasters Restoration of airport operations as quickly as possible	Airport-to-airport mutual aid approach is examined in other countries
Chubu Regional Disaster Management Network: humanitarian logistics base (2012)	Japan	Domestic	Support humanitarian logistics activities Provide a base camp for emergency workers Staging area and warehouse Secure space for staging care unit	Utilization of airports is highly recommended. Shizuoka airport is under examination

Table I.
Current practices in humanitarian logistics bases and the utilization of airports

Program was developed to assist and provide aid during large-scale disasters and emergencies (TRB, 2012). The current practices of governments and international organizations reveal the need for preparedness and response planning in airports to meet the demands that arise during large-scale disasters. The involvement and collaboration of multiple airports are needed for an effective operational base for humanitarian logistics. Despite the current practices and academic research on preparedness planning in the context of airport utilization as a humanitarian logistics base, there have been few studies on specific guidelines and plans for the space layout of such a base. Airports need to acknowledge their current disaster preparedness and response planning in terms of flexibility of space.

2.2 Space planning

Space planning is widely used when developing logical procedures to achieve space configurations. It is needed to address several design parameters such as a client's goals and priorities, an organizational structure and relationships, space allocation criteria, the constraints of fixed building elements and building system interfaces, and security and privacy issues (Addi and Lytle, 2000). In short, the aim of space planning is to find a solution for a space layout within the given constraints. It is a continuous process for achieving a designer's purposes and providing a solution for customers, even though the objectives, constraints, solution procedures, and results presentation methods may not be the same. In the case of office design, space planning is used to meet the clients' request to utilize their available office spaces more efficiently and effectively.

The planning consists of three processes as programming, diagramming, and results presentation (Do *et al.*, 2000). Programming involves defining the requirements of the user and collecting information regarding the functional areas and allocation of each space. In programming, the first step is to determine the objective of the plan. Detailed strategies for finding the architectonic layout can vary (Coyne, 1988; Coyne and Gero, 1991). The planner identifies the objectives of space planning in the first step. Common objectives are minimizing dead space, minimizing cost, minimizing distances between spaces, and maximizing operating efficiency (Sutanthavibul *et al.*, 1990; Shekhawat, 2015a; Liggett and Mitchell, 1981b). The objectives may be qualitative, quantitative, and/or based on multiple criteria defined by the planner (Rio-Cidoncha *et al.*, 2007). In next step, the planner identifies the important parameters in the design process. The formulation of problems can be achieved by asking the following questions: how much available area does the airport have? How many emergency workers are expected to be dispatched? How should the cost function be specified? Asking these questions can be considered a single- or multi-stage process (Liggett and Mitchell, 1981b). Then, the necessary facilities are listed based upon the expected activities in each space or room (Rio-Cidoncha *et al.*, 2007; Hershberger, 2000). Information on lessons learned from past incidents and the current practices of government and humanitarian aid organizations is gathered. After listing the necessary facilities, categorization of the functional areas in each facility makes it possible to investigate the types of specific activities expected to occur in each functional area in a facility and to find similarities between functional areas.

Diagramming involves estimating the approximate area for each functional area and developing an illustration using adjacency or bubble diagrams. Space plans and furniture plans involve the placement of specific furniture, equipment, and interior furnishings (Addi and Lytle, 2000). The creation of adjacency and bubble diagrams is included in this part. According to Do and Gross (2001), the diagrams used in architectural planning help readers to recognize the spatial relations among elements and emergent patterns and configurations. Diagrams also represent the territorial boundaries of spaces in an abstract manner in the planning stage (Do *et al.*, 2000). A strength of diagramming is that it enables planners to convert written information into a graphical format using a standardized design language (White, 1986). Despite the ease of use of the process, diagramming often requires an iterative process for implementation. Difficulties often arise during the thinking and analyzing process stage (Downing and Hubka, 1986).

In the results presentation stage, planners can develop a base schematic plan and enhance it with established preferences. Because space planning is a creative activity, understanding intuitive and arbitrary attributes is natural (Zawidzki *et al.*, 2011). Selection of the most appropriate space plan requires continuous discussions with the planner, airport operator, government officials, and related stakeholders to reach an agreement.

3. Method

3.1 Scope of the framework

This study focused on developing a diagramming process for airports as one of the components of disaster response planning. We incorporated several space layout strategies to address the space constraints related to relief goods and personnel in the first week of post-disaster relief activities. The methodological framework is expressed in Figure 1 following the three processes mentioned in Section 2.2. The systematic space planning procedure was formulated and integrated under one framework. Further details on the diagramming process are illustrated in upcoming sections. The framework is then applied to the Shizuoka Airport as a confirmatory case study.

A humanitarian logistics base in an airport is not a permanent building structure. Instead, these bases usually involve temporary setups or tents as needed in emergencies. Therefore, it does not have the constraints of a fixed building element. The setup must consider not only the approximate total size required but also the functional areas to be included.

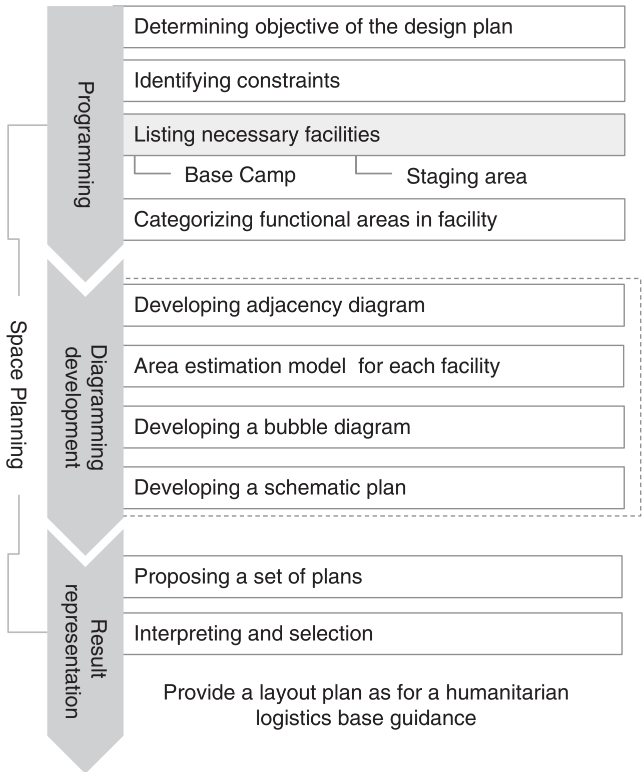


Figure 1.
Space planning framework for a humanitarian logistics base

The selection criteria for such a type of base typically include the availability of open space for loading and unloading goods, the number of extra parking spaces, the base camp area, the presence of a volunteer center for coordinating information, and the accommodations. An airport can function as a humanitarian logistics base in the form of three critical types of facilities: a base camp, staging area, and medical care area. Because the study for a medical care area demands accurate knowledge of the medical system and its components, this study did not address the space layout for emergency medical care.

This study was inspired by the State of Florida (2009b), which has a unified emergency planning operation manual that includes the setup of a base camp and staging area by erecting tents or managing trailers. This unified planning includes several layout plans to meet the requirements of different numbers of emergency workers.

The term "Phase 1 emergency relief" is used in this paper, following Wisetjindawat *et al.* (2014). Phase 1 emergency relief is defined as the period when victims have the minimum requirements for survival. This period is usually determined by the government and is usually from two to seven days. Short-term post-disaster planning (Caunhye *et al.*, 2012) becomes relevant after a disaster strikes a region and involves various activities such as delivering relief goods, evacuating displaced people, and providing transportation and medical care.

3.2 Diagramming development

3.2.1 Developing an adjacency diagram. White (1986) proposed the use of an adjacency matrix diagram in diagramming. This type of matrix is used in architectural planning to visualize the relationships between the functional areas in a building. An adjacency diagram allows designers to identify and estimate proximity requirements. The adjacency diagram is flexible because the demands are able to meet the demands depending on the requirements of the client and designers. The diagram is composed of two-dimensional grids. The functional areas are listed in the top row and in the first column of the matrix. These areas are sometimes numbered so that they can be recognizable for drawing a bubble diagram in next steps. The relative relationships between areas can be marked as very important, desirable, or not critical. Another classification approach classifies the functional areas as mandatory, desirable, neutral, or negative. A third classification approach classifies the areas by immediate proximity and convenient proximity. In the approach proposed in this paper, immediate proximity and convenient proximity are used for the base camp design based on the practical designs of the State of Florida (2009a). Immediate proximity means that it is strongly recommended that the functional areas be located near each other, and convenient proximity means that it would be better that the functional areas were located near each other.

3.2.2 Area estimation for a facility. 3.2.2.1 Calculation for a base camp. The calculation of the total size of the base camp area is shown in Figure 2. Cabinet Office of Japan and

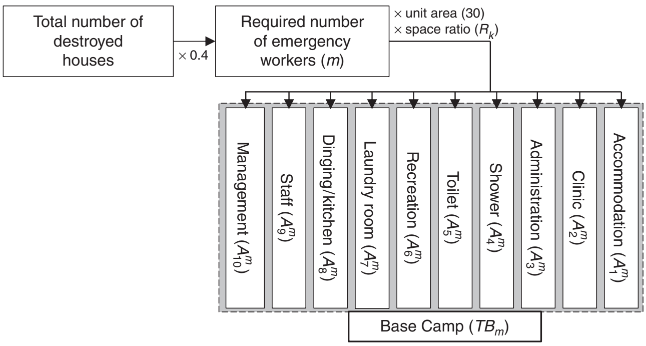


Figure 2.
Estimation of the size of the base camp area

Ministry of Land Infrastructure, Transport and Tourism (MLIT) (2003) proposed a method to estimate the total number of emergency workers that are required for post-disaster activities. This number can be calculated by dividing the total number of destroyed houses by 0.4. However, this is difficult to calculate because estimating the number of destroyed houses beforehand is quite challenging. This study presents several alternatives as standard guidelines. For instance, we set the required number of emergency workers m to 100, 250, 500, 750, or 1,000 to propose standardized guidelines for base design:

$$\mathrm{TB}^m = \sum_{k=1}^{n} A_k^m \tag{1}$$

$$A_k^m = 30mR_k \tag{2}$$

$$\sum_{k=1}^{n} R_k = 1 \tag{3}$$

where TB^m total area of base camp in meters squared required for the total number of emergency workers m, A_k^m area for the functional area k when there are m emergency workers, k identification of each functional area in the base camp, 1: accommodation, 2: clinic, 3: administration, 4: shower, 5: toilet, 6: recreation, 7: laundry room, 8: dining and kitchen, 9: staff, 10: management, R_k relative space ratio of the functional area A_k^m to the entire base, m number of emergency workers required, n number of functional areas in the base camp.

Equations (1) and (2) are used for the calculation of each functional area that is to be included in a base camp. The unit area required per emergency worker is set to 30 m^2 as a minimum and 50 m^2 as a maximum (Cabinet Office of Japan and MLIT, 2003). The minimum unit area is used in the estimation model, as shown in Equation (2). R_k is approximated based on the current practices for base camp design in Florida State Emergency Planning in the US (State of Florida, 2009a). R_k is a constant and is equal to the ratio of each functional area to the total base camp area. However, if the planner decides to select other sets of functional areas instead of the proposed set, a different R_k would be determined based on the intentions of the planner and the restrictive conditions. Thus, R_k is set to 1 when the planner accounts for all functional areas (denoted as A_k^m) when considering the number of emergency workers m. The total area of the base camp is the sum of all functional areas within the base camp.

3.2.2.2 Calculation of the staging area. The total size of the staging area is calculated as shown in Figure 3. The estimation involves several stages based on four assumptions related to the role of the staging area of a humanitarian logistics base in immediate disaster response (Cabinet Office of Japan and MLIT, 2003):

(1) the maximum capacity of the staging area has to support seven days' worth of items for the affected people;

(2) humanitarian aid items are stacked at a maximum height of 120 cm because this is considered a reachable height in storage and staging areas;

(3) humanitarian aid items are stored in different boxes according to item type; and

(4) the minimum required space considers the amount of goods on first day after the disaster

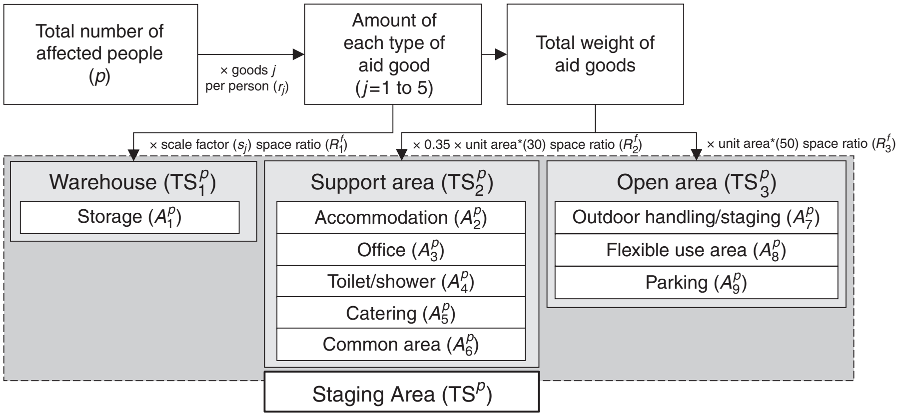


Figure 3.
Estimation of the size of the staging area

Generally, staging area planning focuses on the selection of a site with the required operational capacity and on the availability of equipment such as loading docks, forklifts, and so on (Kapucu *et al.*, 2007). Criteria and considerations for selecting the staging area include the location, location of the center of operations, overall access, helicopter access, safety and security, demobilization, hardstand, equipment, storage, and utilities (Kapucu *et al.*, 2007; State of Florida, 2009a; Cabinet Office of Japan, 2012). Our proposed framework aims to estimate the approximate size of a staging area. Estimating this number (i.e. the area) enables the estimation of the amount of relief goods that can be stored or processed. The area is calculated using a scale factor that converts the weight of relief goods to the total staging area (Cabinet Office of Japan and MLIT, 2003). According to the regional humanitarian logistics hub in Panama, the total staging area consists of three components: the warehouse, the support area for workers, and the open area for loading and unloading goods (UNHRD, 2008):

$$\mathrm{TS}^p = A_1^p = \sum_{v=1}^{3} \mathrm{TS}_v^p \tag{4}$$

$$\mathrm{TS}_1^p = \left(\sum_{j=1}^{5} r_j s_j p \right) R_1^f \tag{5}$$

$$\mathrm{TS}_2^p = \sum_{f=2}^{6} A_f^p = 30\left(0.35 \sum_{j=1}^{5} r_j p \right) R_2^f \tag{6}$$

$$\mathrm{TS}_3^p = \sum_{f=7}^{9} A_f^p = 50\left(\sum_{j=1}^{5} r_j p \right) R_3^f \tag{7}$$

$$\sum_{f=1}^{t} R_v^f = 1 \tag{8}$$

Where, TS^p total area of the staging area (m^2), TS_v^p area of the components of the staging area, v identification of the components of the staging area, 1: warehouse, 2: support area, 3: open area, f identification of each functional area in the staging area, 1: storage, 2: accommodation, 3: office, 4: toilet/shower, 5: catering, 6: common area, 7: outdoor handling/staging, 8: flexible use area, 9: parking, p total number of affected people, t number of functional areas in each TS_v^p, j identification of the items needed for the affected population, 1: water, 2: food, 3: blankets, 4: mandatory kit, 5: temporary toilet, r_j required amount of item j per person (ton/person), $s_j$scale factor of item j obtained by converting a weight to an area (m^2/ton), R_v^f relative space ratio of the functional area A_f^p to the area TS_v^p.

Equation (4) accounts for the required warehouse space. The warehouse is used for storing relief goods such as water, food, blankets, mandatory kits, and temporary toilets. The amount of each type of relief good is estimated according to the allotment presented in Table II. The scale factor is estimated based on the method used in the MLIT (2013b) report. Equation (5) is used to determine the size of the support area based on a unit area of 30 m^2. Equation (6) computes for the size of the open area for staging. A factor of 0.35 is used for the manpower required to process one ton of relief goods in the staging area. The required unit area in the support area is 30 m^2 per person, and that in an open area is 50 m^2/ton, as in MLIT (2013a). The relative ratio of each functional area in each component is 1 and is calculated and derived by practical means (UNHRD, 2008; UNOPS, 2012). In our proposed framework, the staging area also has three essential components according to UNHRD (2008), and the total area is calculated using Equation (8). The areas of the warehouse, the support area, and the space allocated to open areas are calculated, and the size of the individual functional areas in the facility are also determined.

3.2.3 Developing a bubble diagram. After developing an adjacency diagram and estimating each functional area based on the estimation formulation in previous section for each facility, a bubble diagram is now developed. Ruch (1978) described the bubble diagram as an interactive approach for an architect to use to make a decision at every step of the space allocation process. The bubble diagram approach requires considerable experience; therefore, it is best suited for use by experts in presenting a concept than by beginners to study or explore (Lin, 2005). The design objectives of a space layout can be expressed in terms of two basic types of properties: topological and geometric (Arvin and House, 2002). Topological objectives consider the designer's intentions concerning the relative positions and inner correlations of spaces, while geometric objectives consider the designer's intentions concerning the sizes and shapes of spaces.

Architectural bubble diagrams are used to consider the layout of functional areas in a floor plan. Bubble diagrams are used to explore the relationships among the sizes, adjacencies, and approximate shapes of the spaces needed for various activities. They can also be used to explore possible future changes in planning and show simple dimensions and relationships among adjacent spaces (Do and Gross, 2001). A bubble diagram is usually converted from an adjacency diagram to form a graphical representation, as shown in the center of Figure 4. Each functional area is expressed as a circle, and lines are drawn to show the relationships

Table II. Goods allotment per person and scale factor

	Unit amount per person (ton/person)	Scale factor (m^2/ton)
Water	0.0210	1.63
Food	0.0105	3.78
Blanket	0.0030	4.44
Mandatory kit	0.0025	4.44
Toilet	0.0015	6.05
Total	0.0385	20.34

Source: Adapted from MLIT (2013b)

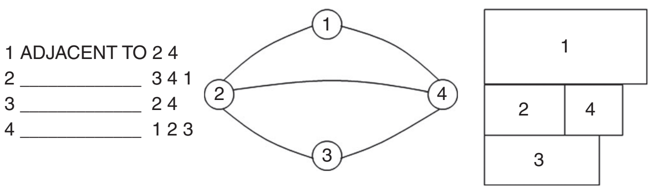
between functional areas. This process assists in creating a rough spatial configuration before an exact location and relative configuration are investigated (Glover and McMillan, 1985).

3.2.4 Developing a schematic plan. A schematic plan is a revised version of the bubble diagram that is used before planning the actual floor plan of a facility, as shown on the right side of Figure 4. When developing a schematic plan from a bubble diagram, a transient process is also required between the two. A schematic plan usually allows the planner to estimate the approximate space allocation and to understand the relationship between an area and its surrounding environment. The design process, from the abstract diagram to the diagram with additional details and finally to the diagram with alternative details, is expressed.

Multiple software programs and computerized tools such as EDGE (Jo, 1993), autoPLAN (Terzidis, 2008), and CPAD (Shekhawat, 2015b) have been developed for the automatic creation of schematic plans. For example, algorithms to assist in space allocation in the planning stage were developed approximately 50 years ago (Liggett and Mitchell, 1981b). Space allocation algorithms for schematic plans are based on the experience of designers. Sometimes, these algorithms involve the demanding task of formulating constraints and requirements (Liggett and Mitchell, 1981a). In addition, a schematic plan is normally restricted by the client's requests, shape constraints, budget constraints, structural requirements, and other constraints (Addi and Lytle, 2000; Liggett and Mitchell, 1981b). One of methods for developing a schematic plan from diagramming is by reducing the number of links between bubble diagrams (Hashimshony *et al.*, 1980). An approach for reaching dimensional plans from adjacency diagrams requires a step-by-step method and can be solved with the PERT algorithm (Roth *et al.*, 1982).

Using rough schematic plans is permissible in emergencies because urgent and tactical decisions are called for during emergencies if a plan is not provided in advance. The major constraint considered in the proposed framework is the amount of land to be utilized as a base at an airport. The following manual steps explain the rectangular formulation, which is taken to derive a schematic plan based on bubble diagrams to determine the approximate size of the base. This is a comprehensive process to incorporate information from bubble diagram about the proximity of a functional area and to acquire the dimensions of a functional area based on the estimation formulation. A systematic process of developing schematic plans from bubble diagrams is outlined below.

First, size estimates are assigned to all functional areas in each facility so that a common factor among these sizes can be derived (i.e. width can be assigned as a common factor that remains constant across all functional areas, and the length of each area will then vary according to their specifications). Second, all areas are laid side by side on a plane so that the planner can check if the total area exceeds the constraining dimensions of available land. If the area exceeds constraints, the planner can then select and reduce or change dimensions of functional areas that exceed the land constraint. This selection is at the discretion of the planner, and some planners prefer to manually develop the plan rather than use such a system (Ruch, 1978). The dimensions assigned in the first step to individual areas are then



Source: Adapted from Ruch (1978)

Figure 4. Graphical representation in an adjacency diagram, a bubble diagram, and a schematic plan

relaxed. New dimensions are given to keep the shape as similar to a square as possible while still meeting adjacency constraints. These iterative steps are conducted and completed until a layout is reached such that all functional areas are contained within the total disaster response base and vacant space is fully utilized in emergencies.

4. Case study

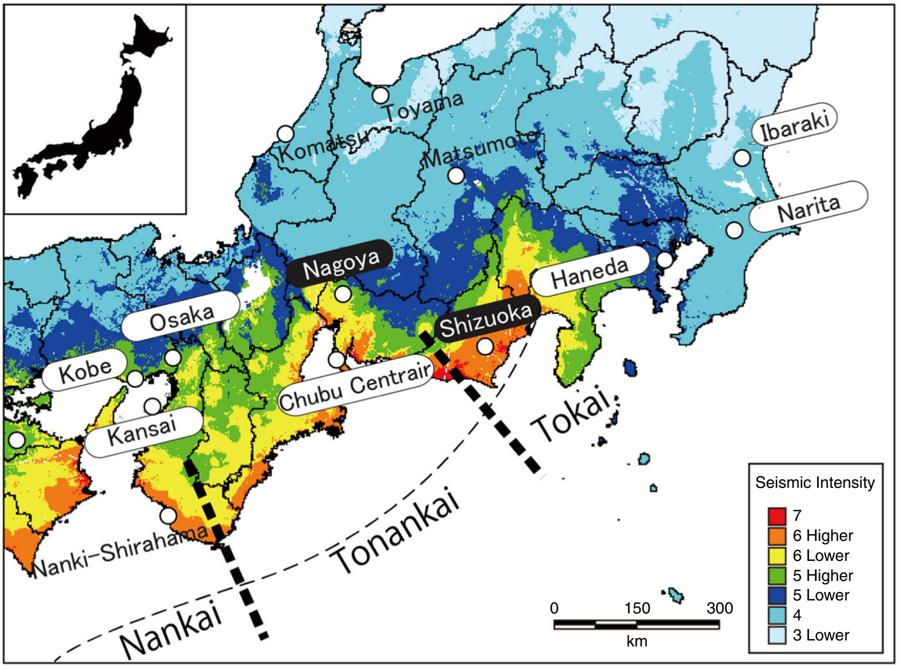
4.1 Disaster management network and assigning airports as a humanitarian logistics base in Japan

As Japan is one of the most disaster-prone countries in the world, disaster management planning is established and is based on the lessons learned from previous disasters. The Chubu Region Disaster Management Network was set up after the Great East Japan earthquake in 2011 to incorporate disaster management strategies from academia and the practices of local and national government agencies (MLIT, 2012). The Chubu region is a central region of Japan's mainland. The suggested "Framework for disaster management network in the Chubu region" considers the alignment of a disaster management network within the region and the assignment of current infrastructure such as community centers, schools, airports, and other public facilities as humanitarian logistics bases. Humanitarian logistics bases in the disaster management network in Japan are selected based on the following criteria: whether or not they are near a node of the infrastructure network with an open space of more than 15 ha and whether or not there is a low-level humanitarian logistics base within the prefecture that has a low probability of flooding by a tsunami, that is located outside the border of a densely inhabited district, and that has optical fiber communications.

Airports in and around the Tonankai region that are designated as humanitarian logistics airports (i.e. the Nagoya Airport and Shizuoka Airport) are highlighted in Figure 5. According to the disaster scenario proposed in MLIT (2013a), the Tonankai region faces the possibility of multiple natural disasters such as earthquakes and tsunamis. Shizuoka Airport is located on the eastern side of the Tonankai region. This airport can cover most of the areas in the Tonankai region along with the Nagoya Airport, which is designated as another humanitarian logistics hub in the region. Therefore, the airports in the Tonankai region are expected to be the region's humanitarian logistics base and usually serve as the prefecture's humanitarian logistics depots (MLIT, 2013a). The current plan for the Shizuoka Airport, which is already assigned as a humanitarian logistics base in the region, includes only rough sketches for the facility and does not mention the logical procedures behind the humanitarian logistics base diagramming. The diagramming model proposed in this paper was applied to the space allocation of the required facilities within the airport. Space allocation is an ongoing issue in disaster management operations among regional and central government agencies in Japan.

4.2 Scenario building

In this study, the objective of the design plan of the Shizuoka Airport is set to cover the maximum number of estimated emergency workers and the affected population. The constraint within the case study is only the land constraint, which is 16 ha. The airport plans to develop a staging area and base camp within the land. The number of affected people and the number of emergency workers required in the Shizuoka Prefecture according to the Tonankai disaster scenario prepared by the Cabinet Office of Japan (2012) are listed in Table III. The maximum coverage rate of the Shizuoka Airport under its current constraint of 16 ha of vacant land (MLIT, 2012) was examined in this case study along with the maximum coverage of the Shizuoka Airport based on the mean number of affected people in each scenario and the total number of emergency workers required in each scenario, as proposed by the Cabinet Office of Japan (2012).



Source: Modified from the Cabinet Office of Japan (2013)

Figure 5. Location of airports in the Nankai Trough Earthquake scenario

Organization	Workers	Scenario	People
Ministry of Defense	11,600		
National Policy Agency	2,540	Basic scenario: Winter/Midnight	54,000
Fire and Disaster Management Agency	2,860	Basic scenario: Summer/Noon	33,000
Total	17,000	Basic Scenario: Winter/Night	42,000

Source: Adapted from the Cabinet Office of Japan (2012)

Table III. Number of emergency workers (left) and number of affected people (right)

4.3 Diagramming for Shizuoka Airport

4.3.1 Base camp. In the diagramming process, the adjacency between a toilet and a shower, for example, is to be considered because these facilities share the water infrastructure line in a base camp. Figure 6 shows the proximity of the functional areas in a base camp as an adjacency diagram. For instance, the shower and toilet areas are assumed to have immediate proximity for the reason mentioned previously.

The approximate size of the base camp area is then calculated based on the estimation formulation. The result is summarized in Table IV. If 1,000 workers are needed to support the humanitarian logistics activities in a base camp in an airport that uses the minimum unit area, the accommodation area would be 9,009 m^2, and the total area of the base camp would be assumed to be 30,000 m^2. The dining and kitchen areas are larger than the accommodation area because more activity space is required between each worker in the first two spaces and because more aisle space is required than that of the sleeping area.

An initial bubble diagram without the size adjustment of each bubble is illustrated on the left side of Figure 7. An adjusted bubble diagram that considers each functional area's relative size according to Equation (2) is presented on the right side of Figure 7. It is clear from the adjusted bubble diagram that 1 and 8 (the accommodation area and the dining/kitchen area, respectively) constitute most of the base camp's gross area.

Figure 8 illustrates the diagramming process of a base camp according to the proposed method. In calculating each functional area, the bubbles in the diagram were transformed into rectangular forms based on a common factor. In order to find the shapes that are as square as possible and as close as possible to the others, we tried several sets of numbers to derive the size. These processes were followed manual iterative steps according to Section 3.2.4.

4.3.2 Staging area. An adjacency diagram is created to understand the space relationships within the facility, as shown in Figure 9. In terms of the proximity, all of the

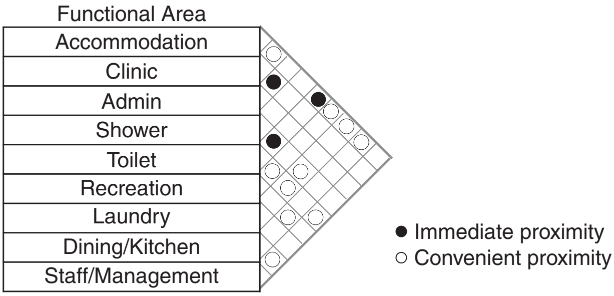
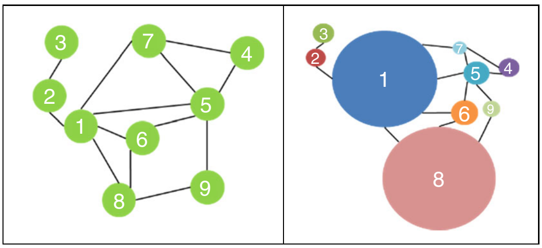


Figure 6.
Adjacency diagram for a base camp

Table IV.
Estimation of a base camp area

Functional area	Size (m^2)	R_k
Accommodation	9009.0	0.30
Clinic	1,126.1	0.04
Admin	1,126.1	0.04
Recreation area	2,252.2	0.08
Toilet	1,407.6	0.05
Shower	1,407.6	0.05
Laundry	563.0	0.02
Dining/Kitchen	12,263.5	0.41
Staff	563.0	0.02
Management	281.5	0.01
Total	30,000.0	1



Functional Area	Number
Accommodation	1
Clinic	2
Admin	3
Shower	4
Toilet	5
Recreation	6
Laundry	7
Dining/Kitchen	8
Staff/Management	9

Figure 7.
Bubble diagram for a base camp

functional areas in the staging area are located close to one another. Basic architectural planning concepts are utilized in building the adjacency diagram.

The number of affected people is assumed to be the total number at the prefecture level in Japan. The result of each staging area's functional area is listed in Table V. To support 10,000 people, the total area required for goods is 1,074.1 m^2. To ensure there will be sufficient space even after the utilization rate of the warehouse is accounted for, it is recommended that 20 percent of the total area is allocated for this use, yielding a total of 1,288.9 m^2 (UNOPS, 2012). Securing sufficient space is critical for responding to unexpected issues in immediate disaster response. We consider this extra 20 percent of the total area reserved flexibly for uses such as necessary aisle space, workspace, or space for the flow of goods.

The total support area required when assisting 10,000 people is 4,042.5 m^2. When supporting 10,000 people, the area required for flexible use and outdoor handling and staging would be 4,812.5 m^2, the required area for parking space would be 9,625.0 m^2, and the total open area would be 19,250.0 m^2. Because there are few guidelines regarding the size of an outdoor handling area within a staging area, the sizes of the outdoor handling area and the flexible-use open area are often assumed to be identical (UNOPS, 2012). The results show the approximate total size estimated for the staging area. To assist 10,000 affected people in an emergency, a staging area of 24,581 m^2 would be required for a humanitarian logistics base.

Figure 10 shows the relative size of the staging area and how the functional areas are related to one another. The open areas are correlated with one another to assist in the smooth flow of relief goods. In terms of proximity, the adjacency of the flexible-use space and the parking space would be convenient for quick response to unexpected events in an emergency. The parking space would occupy the largest part of the staging area because of the unpredictable number of vehicles and the amount of relief goods that may clog the area. Figure 11 illustrates the diagramming of a staging area. We follow our method presented in Section 3.4.4.

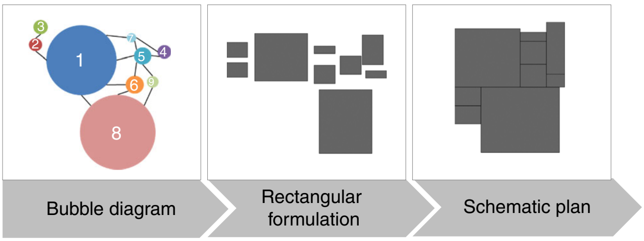


Figure 8.
Diagramming process for a base camp

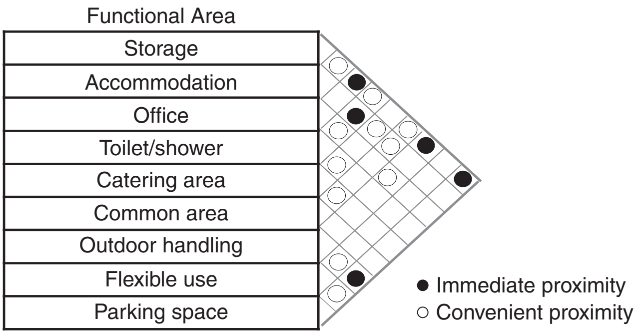
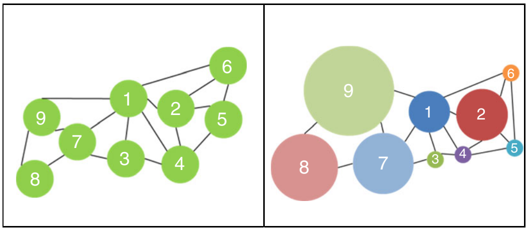


Figure 9.
Adjacency diagram for a staging area

Table V.
Estimation of a staging area

Functional area	Size (m^2)	R_v^f
Warehouse area		
Water	342.3	
Food	396.9	
Blanket	133.2	
Mandatory kit	111.0	
Toilet	90.7	
Total area	1,074.1	1
Total area (120%)	1,288.9	
Support area		
Accommodation	3,234.0	0.80
Office	202.1	0.05
Toilet/shower	202.1	0.05
Catering area	202.1	0.05
Common area	202.1	0.05
Total	4,042.5	1
Open area		
Outdoor handling and staging	4,812.0	0.25
Flexible use	4,812.0	0.25
Parking space	9,625.0	0.50
Total	19,250.0	1
Total staging area	24,581.0	



Functional Area	Number
Storage	1
Accommodation	2
Office	3
Toilet/shower	4
Catering area	5
Common area	6
Outdoor handling and staging	7
Flexible use	8
Parking space	9

Figure 10.
Bubble diagram for a staging area

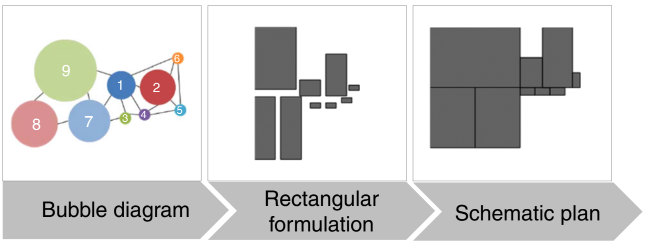


Figure 11.
Diagramming process for a staging area

4.3.3 Humanitarian logistics base layout. The forms shown in Figures 8 and 11 are suggested in the layout. Figure 12 presents the suggested layout for a humanitarian logistics base within the current layout plan of the Shizuoka Airport. The airport has a total gross area of 500 ha, and the space available is assumed to be 16 ha. The approximate size of the current site is $280 \times 580\, m^2$. In this case study, we examined the maximum acceptable

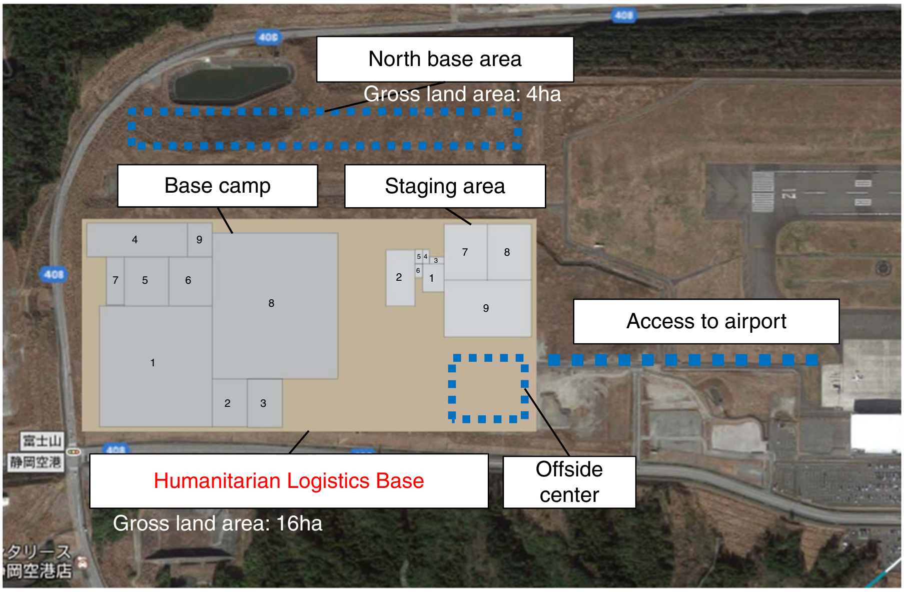


Figure 12.
Layout plan for the Shizuoka Airport

number as 17,000 emergency workers and 43,000 affected people in a disaster scenario. These numbers were utilized as inputs for each estimation model. The results indicate that the Shizuoka Airport humanitarian logistics base covers 26.8 percent of the total number of emergency workers and affected people, i.e., the base can provide assistance to 4,250 workers and 10,750 affected people as the maximum acceptable numbers in this proposed base layout within the land constraint.

4.4 Discussion

We applied a method to the Shizuoka Airport case and found that the Shizuoka Airport can cover 26.8 percent of the affected population and emergency workers in a disaster scenario. Applying the method to a case study is easy to replicate, however, an examination of the feasibility of the proposed layout plan is challenging. To investigate the feasibility of the proposed layout plan, as in Section 4.1, we interviewed officials of the Shizuoka Prefecture's Transportation Infrastructure Department on December 6, 2013 about the applicability of the method. Based on the interview responses, we also confirmed that the feasibility of such disaster response planning in advance of a disaster is difficult. The study offers the following suggestions for developing a humanitarian logistics base in an airport.

First, the planning of a humanitarian logistics base should be treated as a flexible space guideline rather than a rigid plan. Because of the uncertainties associated with catastrophic events, it is not possible to divide an exact space with walls or with any permanent structures as in ordinary buildings; instead, the space must be divided using temporary structures such as tents, trailer units, partitions, and so on. In addition, we have to detect the available facilities or vacant space that can be converted for disaster response purposes. Second, the priorities of functional areas and facilities depend highly on the airport's existing capacity and the impact of the disaster. For instance, the Shizuoka Airport has sufficient space for use as a disaster base on the 16 ha of land on the left side of the terminal building. Therefore, airport officials believe that the Shizuoka Airport has the potential to be utilized in a disaster scenario. However, many regional airports in Japan may not have such vacant space as the Shizuoka Airport. This calls for the development of a compact humanitarian logistics base by prioritizing the most likely functions in a post-disaster situation. This could be done by deciding the necessary functional areas during programming in the procedure.

5. Conclusions

Despite the significant role of airports as a humanitarian logistics base in previous disasters, there is a need to study space planning guidelines for an airport in a disaster response more elaborately. This paper proposes a diagramming method for the utilization of an airport as a humanitarian logistics base. The outputs are obtained by integrating an estimation model and architectural planning processes. The method is used to estimate the approximate size of a base camp and staging area based on the number of emergency workers and the total amount of relief goods. In addition, the humanitarian logistics were visualized using diagramming from the output of a bubble diagram and a schematic plan. The Shizuoka Airport case study presents the internal configuration of the schematic plan developed using the proposed framework. Our study provides operational insights for the disaster response planning efforts of local and central governments and international humanitarian organizations. Thus, the model provides a generic methodology, so that the study can also be applied to vacant spaces in other critical nodes in impacted regions such as ports, stadiums, schools, or parks.

The study considered the available land space as a constraint and the maximum coverage rate of the affected population and emergency workers as the main objective. However, we find the following research directions very useful for further steps. First, as airports are critical infrastructure components in a region, an integrated approach to their utilization involving urban planning principles should be considered. For example, the relationship between the base and other facilities in an airports as well as road conditions, lifeline networks, etc. should be reflected in the planning. Second, legislation issues and engineering constraints for facilities within and around airports must be reflected. Third, the development of a mathematical model for the measurement of the space and the location of functional areas would allow decision makers to choose the best-fitting design from among different alternatives. Some types of disasters and damage to the airport may affect available open space. Acknowledging these uncertainties as constraints, we may apply the proposed methodology in given areas of limited space. If the space is insufficient for all activities, priorities are to be assigned to functional areas in each facility in the base. This requires the consideration of multiple constraints and objectives. In addition, decision criteria should be developed for use by nations and regions in enhancing airport operations as part of the immediate disaster response. As this study provides only a confirmatory case study, further research is recommended for validating the methodology.

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