Airport Design Guideline as a Humanitarian Logistics Base

Sunkyung CHOI[1] and Shinya HANAOKA[2]

[1] Dept. of International Development Eng., Tokyo Institute of Technology
(2-12-1 O-okayama Meguro-ku, Tokyo 152-8550, Japan)
E-mail:choi.s.ae@m.titech.ac.jp
[2]Associate Professor, Dept. of International Development Eng., Tokyo Institute of Technology
(2-12-1 O-okayama Meguro-ku, Tokyo 152-8550, Japan)
E-mail:hanaoka@ide.titech.ac.jp

Airports play a critical role as a node for humanitarian logistics when natural disaster hits a region. However, there are no guidelines governing space allocation of an airport. This paper proposes a design guideline for an airport as a humanitarian logistics base concerning two components mainly: 1) base camp (space for emergency workers), 2) staging area (area to deal with sorting, storing, loading and unloading relief goods). We develop a methodology to estimate total area of the base and visualize layout by space planning. The result suggests approximate size and layout of a base camp and a staging area to be included as a humanitarian logistics base. The space planning methodology is further applied to Shizuoka airport as a case study.

Key Words : *humanitarian logistics, emergency planning, staging area, base camp, space allocation*

1. INTRODUCTION

Following the March 2011 earthquake and tsunami, there was a certain need to revisit disaster management planning regarding natural disaster. In order to build a sound disaster preparedness plans in many disaster prone cities and countries, this research would lead academics and practitioners to attain attention for disaster management planning.

In emergency logistics or humanitarian logistics, it is known that staging area, logistics center, and base camp are necessary within a region in order to be prepared to secure enough commodities and human resources in case of disaster. Some argues that it is preferable if staging area can be set up within an airport since most regional airports have vacant space which enables various activities, accessibility, hard stand area for loading/unloading goods, and helipads.

Despite critical role of airports in humanitarian logistics, some limitations still lie in airports space usage in post-disaster. Such space constraints are mentioned in Hanaoka *et al.* (2013)[1)]. The author argues that airports need to deal with the space constraints in order to be prepared well enough to deal with humanitarian logistics operation in airports. In this study, two space constraint issues are to be answered by research question. Two issues are space for emergency workers and place for relief goods.

The fundamental question that the author intended to address is how to plan space allocation of a humanitarian logistics base in an airport. By answering this question, this research aims to propose a design guideline for an airport as a humanitarian logistics base. There are three objectives that derived from the research goal.

1) Estimate area of required facilities in a humanitarian logistics base
2) Make a bubble diagram for each facility
3) Draw a schematic plan for Shizuoka airport based on scenario analysis

By achieving objectives, this research would make an attempt to deal with space limitation issues in an airport in post-disaster and assist effective decision making in planning a humanitarian logistics base in an airport with regard to space planning.

The rest of the paper is constructed as follows. Section 2 explains a proposed framework for methodology and its developed methodology is mentioned in Section 3. Section 4 gives estimation result of area and diagram of a base camp and a staging area. Section 5 suggests layout of a humanitarian logistics in Shizuoka airport as a case study. Section 6 covers discussions and Section 7 concludes the study.

2. LITERATURE REVIEWS AND RESEARCH FOCUS

In large scale emergencies, unexpected amount of people and goods gather in airports. Perkins (2013)[2] mentions importance of airports and their operation in disaster. It is critical that the roles of airports in a disaster and the impact of those roles would be acknowledged by airports operators, local governments, and humanitarian logistics agencies in order to share information for effective disaster response plan. Unsolicited supplies in fact clog airports and warehouses (Cassidy, 2003[3]; Murray, 2005[4]) in post-disaster and create redundancies (Sowinski, 2003)[5].

Some other problems occurring at airport in post-disaster are congestion in runway, refueling issue, communication among players, and congestion in warehouse and apron area. The main focus of problems is congestion occurred by limited capacity. Because each airport has different capacity on its infrastructure, limited amount or capacity of airport's landside and airside infrastructure is difficult to change. Therefore, it is important to manage and operate efficiently and effectively within in current airport layout in operating humanitarian logistics.

Related research fields to this paper are architecture, air transport, and humanitarian logistics. Positioning topic as an intersection of three studies, this research attempts to solve research problem in interdisciplinary way.

3. METHODOLOGY

(1) Methodology framework

A proposed methodology would be formulated by unfying ideas of practical projects and acadmic researches. Current practices of humanitarian logistics are mostly led by government operation. State of Florida (2009) has a unified emergency planning operation manual including set up of a base camp and a staging area by erecting tent or managing trailers. Kapucu *et al.* (2007)[6] mentions that there are no officially-documented guidelines regarding staging area selection as emergency management planning. Also, among few litertature reviews regarding issues, most topic focuses on selection of a staging area and not compenent of it. This research follows a methodology framework as in Fig.1 in order to assist design guideline for space allocation of an airport as a humanitarian logistics base. This proposed methodology will enable to estimate approximate size of the total base in an airport and to visualize each facility's inner space relationships by a bubble diagram and adjacency matrix.

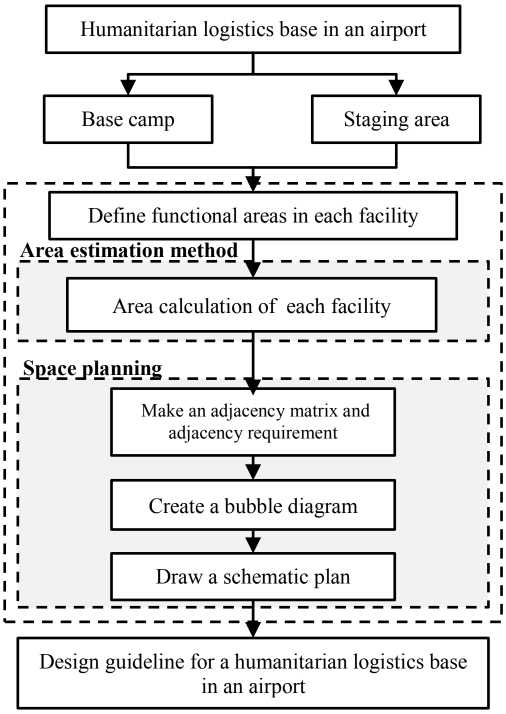


Fig.1 Framework for a humanitarian logistics base

(2) Area estimation method

a) Calculation method for a base camp

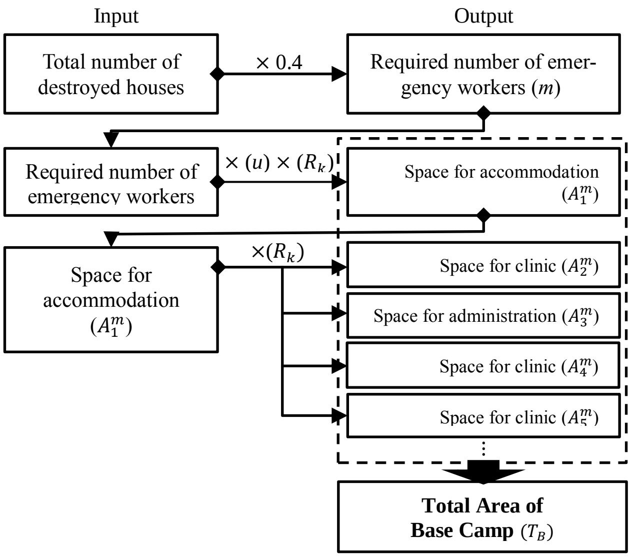


Fig.2 Calculation flow for a base camp

Since it is the first attempt to have a base camp inside of an airport in Japan, there are few literatures. Data was collected through government's project papers and practical emergency planning in Florida, U.S.A.[7] Fig.2 explains flow for a base camp estimation. In this paper, required number of emergency workers (m) is defined as 100, 250, 500, 750 and 1000 in this study in order to support standardized guideline for base design. The following equation (1) and (2) is for calculating each functional area to be included in a base camp.

Unit area u is defined as 30m^2 for minimum estimation and 50m^2 for maximum unit area (MLIT, 2003)[8]. R_k is estimated based on current practices of base camp design in Florida State Emergency Planning of United States.

$$T_B = \sum_{k=1}^{n} A_k^m \; (k = 1, \cdots, 10) \tag{1}$$

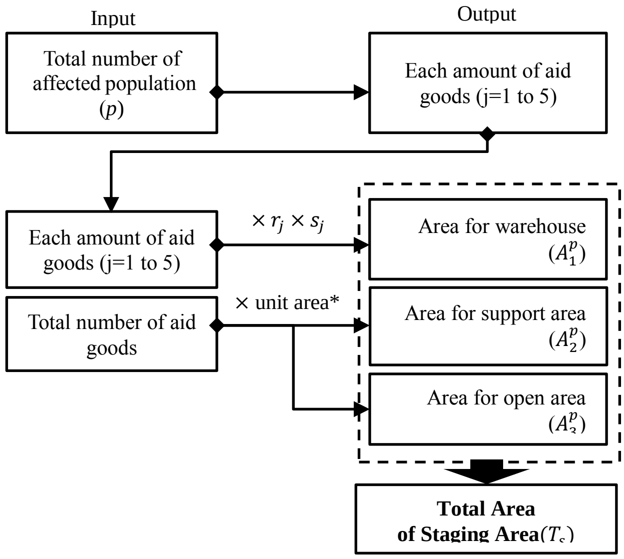
$$A_k^m = m \times u \times R_k (k = 1, \cdots, 10) \tag{2}$$

T_B total area of base camp
A_k^m area for functional space k when total m number of emergency workers
k identification of each functional space in base camp
- k = 1: space for accommodation
- k = 2: space for clinic
- k = 3: space for administration
- k = 4: space for shower room
- k = 5: space for toilet
- k = 6: space for recreation center
- k = 7: space for laundry room
- k = 8: space for dining and kitchen
- k = 9: space for staff
- k = 10: space for management

R_k ratio of functional space A_k^m to A_1^m, $R_k = 1$ when k = 1
m number of required emergency workers
u unit area for base camp per one emergency worker

Total area of base camp is a sum of all functional areas within the area. Functional areas are noted as A_k^m, when considering m number of emergency workers.

b) Calculation method for a staging area



Unit area* for support area is 30m^2 and for open area is 50m^2

Fig.3 Calculation flow for a staging area

Calculation flow for size of staging area is calculated based on Fig.3. Staging area estimation consists of several stages. It is based on several assumptions as the following:

1) Maximum capacity of staging area aims to support 7 days support items for affected people.
2) Humanitarian aid items are stacked at 120cm at most since this number is considered as reachable height in storage and staging area.
3) Humanitarian aid items are carried in a different box according to an item.

Since total number of affected population (p) is difficult to get actual data, it is simplied from the second step of the calculation flow. In this study, the number of affected population is assumed as a total number of affected populations within in a prefecture and defined as 10000, 30000, 50000, and 70000. Total area of a staging area consists of three parts which are warehouse, support area for workers, and open area for loading and unloading goods. It is explained in equation (3).

$$T_S^p = A_1^p + A_2^p + A_3^p \tag{3}$$

$$\begin{aligned} A_1^p &= \sum_{j=1}^{n} A_j^p \; (j = 1, \cdots, 5) \\ &= \sum_{j=1}^{n} r_j \times p \times s_j \quad (j = 1, \cdots, 5) \end{aligned} \tag{4}$$

$$A_2^p = \left(\sum_{j=1}^{n} r_j \times p \right) \times 30 \; (j = 1, \cdots, 5) \tag{5}$$

$$A_3^p = \left(\sum_{j=1}^{n} r_j \times p \right) \times 50 \; (j = 1, \cdots, 5) \tag{6}$$

T_S total area of staging area
A_1^p area for warehouse when total number of affected population are p
A_2^p area for support area when total number of affected population are p
A_3^p area for open area when total number of affected population are p
p total number of affected population
j identification for items needed for affected population
- j = 1: water
- j = 2: food
- j = 3: blanket
- j = 4: mandatory kit
- j = 5: temporary toilet

r_j required amount for item j per one person
s_j scale factor of item j from converting weight to area

Equation (4) explains required space for warehouse in order to store humanitarian aid goods.[9] Aid goods dealt in this study area water, food, blanket, mandatory kit, and temporary toilet. Number of humanitarian aid goods are assumed on the basis of goods allotment in Table 1. Scale factor is estimated based on methodology of MLIT, 2013. Equation (5) is for support area with unit area of 30m^2 and equation (6) explains open area for staging area. Unit area follows MLIT, 2003. Area for warehouse, area for support area, and area for open area is calculated and each functional areas in area is derived.

Table 1 Goods allotment per person and scale factor

Source: Adapted from MLIT, 2013[10)]

	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

(3) Space planning

a) Adjacency matrix

Adjacency matrix is used in architectural planning in order to see relationship between each functional area in a building.[11)] The adjacency diagram would let designers to identify the proximity requirements. This does not have definite answer for concluding the best answer and there may lay various approaches.

b) Bubble diagram and schematic plan

Bubble diagram is an interactive approach for an architect to make a decision at every step for space allocation process.[12)] Architectural bubble diagrams are used to consider layout of functional areas in a floor plan. Bubble diagrams are to explore relationships among the sizes, adjacencies, and approximate shape of the spaces needed for various activities. A schematic plan is a revised version of bubble diagram before planning actual floor plans of a facility as in Fig.4. Design process from abstract diagram, diagram with additional details, and diagram with alternative details will be expressed. (Do. and Gross., 2001).[13)]

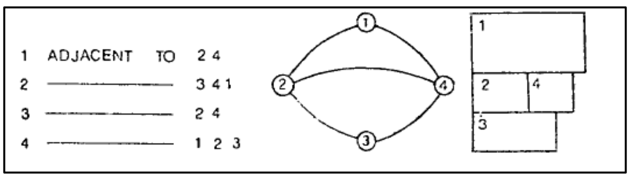


Fig.4 Graph representation in bubble diagram
Source: Adapted from Ruch (1978)

4. RESULT

(1) Base camp

a) Functional area estimation in a base camp

Approximate size of base camp area is calculated in Table 2. If 1000 workers would support humanitarian logistics in an airport in a base camp adapting a minimum unit area, accommodation area is approximately 9009.00m^2 and total area for base camp is assumed as 3ha.

Table 2 Base camp area estimation

Unit:m^2

Emergency workers	1000	750	500	250	150	100
Accommodation	9009.0	6756.7	4504.5	2252.2	1351.3	900.9
Clinic	1126.12	844.5	563.0	281.5	168.9	112.6
Admin	1126.1	844.5	563.0	281.5	168.9	112.6
Recreation center	2252.2	1689.1	1126.1	563.0	337.8	225.2
Toilet	1407.6	1055.7	703.8	351.9	211.1	140.7
Shower	1407.6	1055.7	703.8	351.9	211.1	140.7
Laundry	563.0	422.2	281.5	140.7	84.4	56.3
Dining/Kitchen	12263.5	9197.6	6131.7	3065.8	1839.5	1226.3
Staff	563.0	422.2	281.5	140.7	84.4	56.3
Management	281.5	211.1	140.7	70.3	42.2	28.1
Total	30000	22500	15000	7500	4500	3000
Total(ha)	3	2.25	1.5	0.75	0.45	0.3

b) Space planning

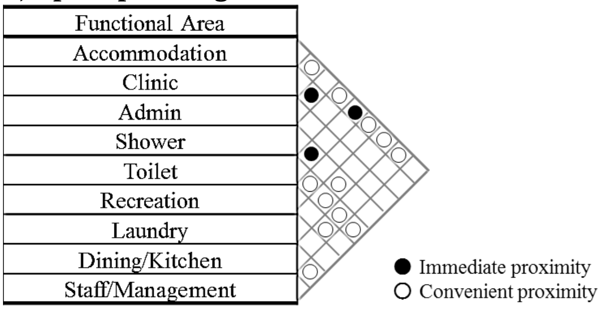


Fig.5 Adjacency matrix in a base camp

Immediate proximity and convenient proximity are assumed on base camp design from practical designs of State of Florida (2009). Immediate proximity means strongly recommended being located near each other, and convenient proximity means better to be located near each other. For example, adjacency between toilet and shower is considered as an immediate proximity since it shares same water infrastructure line within in a base camp.

Table 3 Functional area in a base camp

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

An initial bubble diagram and its adjusted figure with considered each functional area's relative size is in Fig.6. Staff area and management area are combined for simplicity in a diagram. It can be easily seen that 1 and 8 which are accommodation area and dining/kitchen area consist most of base camp gross area. The largest part within base camp is dining/kitchen area and accommodation area.

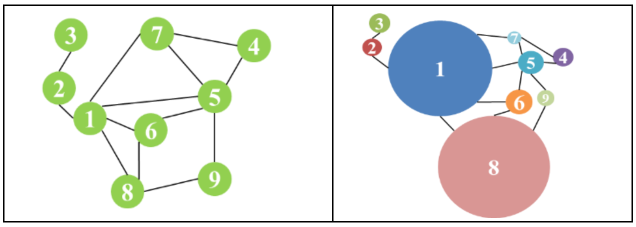


Fig.6 Bubble diagram for a base camp

(2) Staging area

a) Staging area functional area estimation

Estimation for storage in staging area is indicated in Table 3-2. In order to support 10000 people, total sum of each area for goods required is assumed as 1074.15 m^2. In order to secure enough space, 120% of total sum of each area is regarded as 1288.98 m^2.

Table 4 Storage area estimation in a staging area

Unit:m^2

Affected population	10000	30000	50000	70000
Water	342.3	1026.9	1711.5	2396.1
Food	396.9	1190.7	1984.5	2778.3
Blanket	133.2	399.6	666.0	932.4
Mandatory kit	111.0	333.0	555.0	777.0
Toilet	90.7	272.2	453.7	635.2
Total area	1074.1	3222.4	5370.7	7519.0
Storage area	**1288.9**	**3866.9**	**6444.9**	**9022.8**

Table 5 shows estimation for support area for workers in staging area. Total support area when assisting 10000 people is 4042.5 m^2. Table 3-4 shows estimation for open space in staging area. When supporting 10000 people, outdoor handling and staging is required as 4812.5m^2 and flexible use is as 4812.5 m^2 and parking space would be as 9625 m^2.

Table 5 Support area estimation in a staging area

Unit:m^2

Affected population	10000	30000	50000	70000
Workers	135	404	674	943
Accommoda-tion	3234	9702	16170	22638
Office	202.12	606.37	1010.62	1414.87
Toilet/shower	202.12	606.37	1010.62	1414.87
Catering area	202.12	606.37	1010.62	1414.87
Common area	202.12	606.37	1010.62	1414.87
Support area	**4042.5**	**12127.5**	**20212.5**	**28297.5**

Table 6 shows open area estimation. Total open space would be approximately 1.9ha when supporting 10000 people. Outdoor handling and staging area and flexible use are assumed to be the same size.

Table 6 Open area estimation in a staging area

Unit:m^2

Affected population	10000	30000	50000	70000
Outdoor handling and staging	4812	14437	24062	33687
Flexible use	4812	14437	24062	33687
Parking space	9625	28875	48125	67375
Open area	**19250**	**57750**	**96250**	**134750**

The result from Table 7 suggests an approximate size of total staging area estimation combining Table 4, Table 5, and Table 6. In order to assist 10000 affected population, staging area is required as 2.45 ha within a humanitarian logistics base.

Table 7 Total area estimation of a staging area

Affected population	10000	30000	50000	70000
Total Staging Area(m^2)	24581	73744	122907	172070
Total Staging Area(ha)	2.45	7.37	12.29	17.2

b) Space planning

The result of space planning are adjacency matrix and bubble diagram. Adjacency matrix is drawn in order to understand space relationships within a facitliy as in Fig.7. All functional areas in a staging area are located close to each other concerning proximity. Basic architectural planning concept is utilized in building adjacency matrix. Immediate proximity means strongly recommended being located near each other, and convenient proximity means better to be located near. For example, adjacency between flexible use space and parking space would be convenient proximity in order to respond unexpected happenings in emergencies.

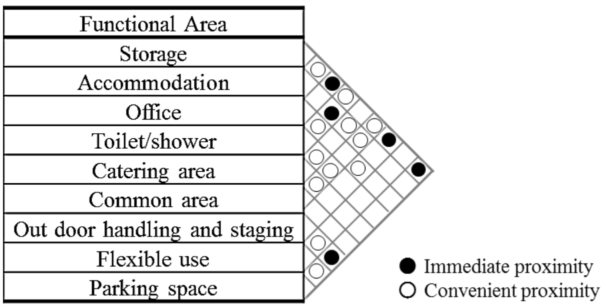


Fig.7 Adjacency matrix in a staging area

Fig.8 shows relative size of staging area and how each functional area is related to each other. Open area are correlated each other in order to assist smooth flow of aid goods. Parking space would take the position as the biggest part for staging area due to unexpected amount of vehicles and aid goods may clog in the area. (1: Storage, 2: Accommodation area, 3: Office, 4: Toilet/shower, 5: Catering area, 6: Common area, 7: Outdoor handling and staging, 8: Flexible use space, 9: Parking space)

Table 8 Functional area in a staging area

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

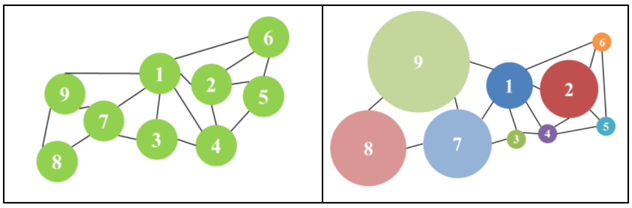


Fig.8 Bubble diagram for a staging area

5. CASE STUDY

(1) Scenario building

According to disaster scenario given by MLIT (2013)[14], Tonankai disaster would be consisted of multiple natural disasters such as earthquakes and tsunamis. Shizuoka airport is in eastern side of Tonankai region. It can cover most regions in Tonankai region along with Nagoya airport which is assigned as another humanitarian logistics in the region.

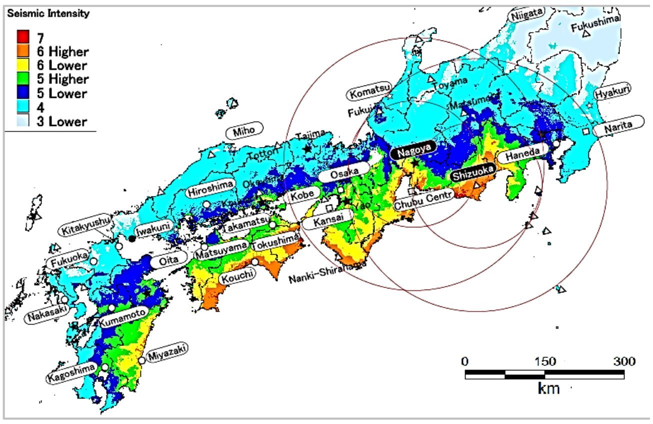


Fig.9 Coverage of Shizuoka airport within 60 minutes

As in Fig.9 and Fig.10, within 2 hours-distances by air transport, support from Shizuoka airport can reach up to Oita or Iwakuni which is the western part of Tonankai region.

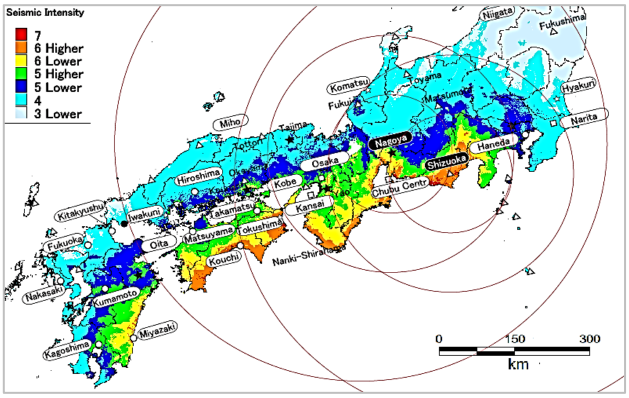


Fig.10 Coverage of Shizuoka airport within 120 minutes

In Tonankai disaster scenario by Cabinet office of Japan (2007), affected population and needed emergency workers in Shizuoka prefecture are as in Table 9 and Table 10. Case study will examine maximum coverage rate of Shizuoka airport under current constraint of vacant 16ha as a land space.[15]

Table 9 Number of emergency workers in scenario[16]

Organization	People
Ministry of Defense	11,600
National Policy Agency	2,540
Fire and Disaster Management Agency	2,860
Total	17,000

Table 10 Number of affected population in scenario

Scenario	People
Basic scenario: Winter/Midnight	54,000
Basic scenario: Summer/Noon	33,000
Basic Scenario: Winter/Night	42,000
Mean number of affected population	43,000

Table 11 examines maximum coverage of Shizuoka airport according to coverage rate of affected population and number of emergency workers. Shizuoka airport is assumed to cover between 25% and 30% of total required emergency workers and number of affected population. Current constraint of a humanitarian logistics base land area is assumed approximately as 16ha. Following scenario building, the study will suggest a schematic plan within Shizuoka airport by adapting methodology.

Table 11 Scenario by different coverage rate

	Facility	People	Area(ha)
Coverage rate: 20%			
	Base camp	3,400	10.2
	Staging area	8,600	2.1
	Total area		12.3
Coverage rate: 25%			
	Base camp	4,250	12.7
	Staging area	10,750	2.6
	Total area		15.3
Coverage rate: 30%			
	Base camp	5,100	15.3
	Staging area	12,900	3.6
	Total area		18.9

(2) Space planning for Shizuoka airport

Fig.11 and Fig.12 shows space planning of a base camp and a staging area by the proposed methodology. Initial bubble diagrams are developed into a schematic plan as a output in Fig.13. Fig. 13 is a combined schematic plan as a humanitarian logistics base. This schematic plan is drawn based on area estimation and its dimensions are determined through iterative process. Fig.14 shows a layout for a humanitarian logistics base within current Shizuoka airport layout plan. It is estimated that gross land area of a base may be estimated around 16ha.

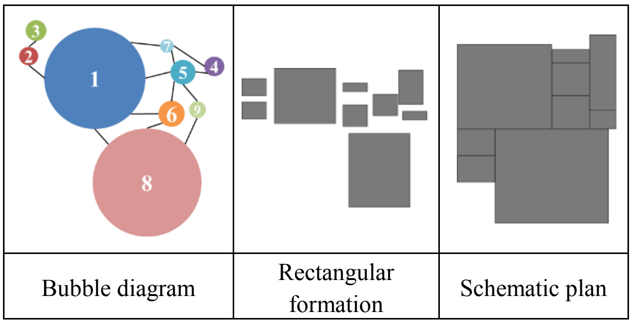


Fig.11 Base camp planning process

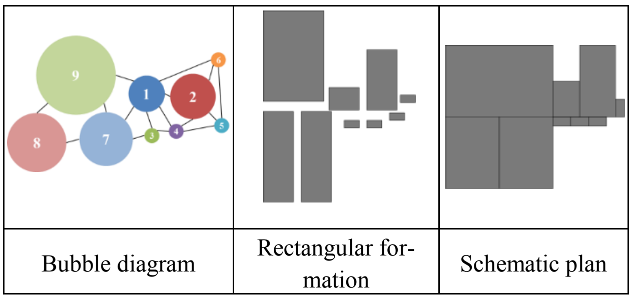


Fig.12 Staging area planning process

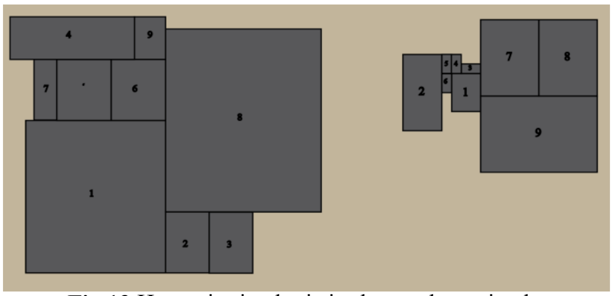


Fig.13 Humanitarian logistics base schematic plan

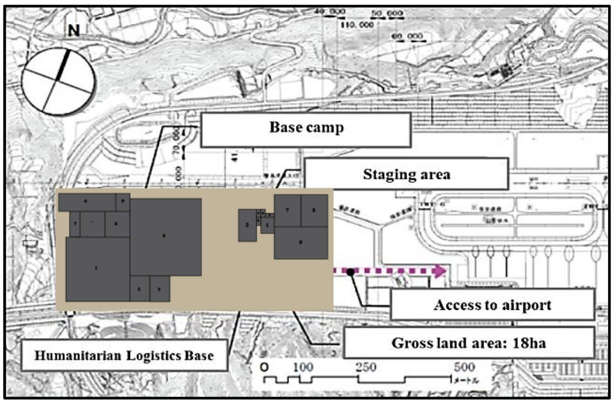


Fig.14 Layout plan for Shizuoka airport

6. DISCUSSIONS

The result suggests an approximate size of a base camp and staging area. It also visualizes by following space planning as an output of a bubble diagram and a schematic plan. The case study of Shizuoka airport suggested that schematic plan may be larger than current vacant place in Shizuoka airport since it didn't consider space for aisles between goods in warehouses. The other reason is that hardware of architctural planning such as thickness of walls or other infrastructures allocations are not included. The further discussions is also needed about defining relationship between a base and its near circumstances in an airport as a part of urban planning perspective

7. CONCLUSIONS

This study proposed a design guideline for a humanitarian logistics base in an airport, and has presented its conclusion by integrating calculation model and architectural planning methodologies. This study is unique in a sense that it tackled an issue in border with architectural planning, humanitarian logistics and air transport studies.

This research had an attempt in solving mainly two space layout problems occurring in an airport by achieving three objectives in order. First objective covers about estimation method and defines what are required as a humanitarian logistics base. Second objective tried to demonstrate relationship between each functional area by adjacency matrix and bubble diagram. The last objective suggested schematic plans for Shizuoka airport as a case study. This research is an initiative research in airport as a humanitarian logistics base with various disciplines. This thesis investigated each facility space allocation and its inner space planning issues.

Several future studies might focus on the following remaining issues such as mathematical model development concerning airport constraints. Also, integration with urban planning perspective can be later developed in understanding relationship between the base and surrounded environment.

REFERENCES

1) Hanaoka, S., Indo, Y., Hirata, T., Todoroki, T., Aratani, T., and Osada, T. :Lessons and Challenges of Airport Operation during a Disaster: Case Studies of Iwate Hanamaki Airport, Yamagata Airport, and Fukushima Airport during the Great East Japan Earthquake, *Journal of JSCE, Division F: Construction Engineering and Management*, In Press. 2013.
2) Perkins, Jeanne B.: Roles of Airports in Regional Disasters: Lessons on Disaster Response, Short-Term Disaster Recovery, and Long-Term Economic Recovery for the San Francisco Bay Area, 2013. Retrieved from http://quake.abag.ca.gov/wp-content/documents/Airports/Role-of-Airports-in-Disasters-Perkins-FINAL-May-31-2013.pdf
3) Cassidy, W.B.: A logistics lifeline. *Traffic World*, Vol. 27, No.1, 2003.
4) Murray, S.: How to deliver on the promises: supply chain logistics: humanitarian agencies are learning lessons from business in bringing essential supplies to regions hit by the tsunami. Financial Times, 9. 2005.
5) Sowinski, L.L.: The lean, mean supply chain and its human counterpart. *World Trade*, Vol. 16, No.6, p.18, 2003.
6) Kapucu, N., Lawther, W., Pattison, S. :Logistics and staging areas in managing disasters and emergencies, *Journal of Homeland Security and Emergency Management*, Vol. 4, No. 2, pp.1-17, 2007.
7) State of Florida, Division of Emergency Management Logistics Section: State of Florida: State Unified Logistics Plan, 2009.
8) MLIT, Nagoya Regional Disaster Prevention Network Working Group.: Simulation on Estimation Ideas of Case Studies, 2003.
9) State of Florida, Division of Emergency Management Logistics Section: State Comprehensive Emergency Management Unified Logistics Section, Base Plan: Annex 2355, 2009.
10) MLIT, Shikoku Transport and Tourism Bureau.: Investigation on Comprehensive Humanitarian Logistics Network Construction focused on Transport and Storage, 2013.
11) Demkin, J. The American Institute of Architects.: The Architect's Handbook of Professional Practice, 13th edition, 2001.
12) Ruch, J. : Interactive Space Layout: A Graph Theoretical Approach, *Proceedings of the 15th conference on Design automation*, pp.152-157, 1978.
13) Ellen, Y. Do and Mark, D. Gross. : Thinking with Diagrams in Architectural Design. *Artificial Intelligence Review*, Vol. 15, pp. 135-149, 2001.
14) MLIT, Chubu Region Disaster Management Network Working Group.: Chubu Region Disaster Management Network for Tokai, Tonankai, Nankai Disaster Scenario, 2013.
15) MLIT, Chubu Region Disaster Management Network Working Group.: Chubu Region Disaster Management Basic Strategy, 2012.
16) Cabinet Office, Government of Japan.: Tonanki, Tokai Disaster Response Plan, 2007.

(Received August 2, 2013)