Dynamic Allocation of Mobile Units in Disaster Support: A Case Study of the Noto Earthquake

Shin Tsuchiya
Tokyo Metropolitan University
mtsutiya@tmu.ac.jp

ABSTRACT

This study analyzes how mobile units were used during the 2024 Noto Peninsula Earthquake and clarifies how needs changed over time and what information management issues arose. Field investigations in Suzu City and Shika Town show that demand for mobile toilets, laundry units, and residential trailers shifted as the recovery process progressed. In several cases, mismatches between unit specifications and evacuee composition reduced effectiveness. Existing disaster information systems are largely sector-based and designed around fixed facilities, making it difficult to coordinate mobile resources in response to changing conditions. To address this gap, this study proposes a two-layer information management model that links individual-level data with mobile unit data through aggregated indicators. The proposed Dynamic Unit Allocation Framework provides a foundation for managing mobile disaster support more effectively.

Keywords

Disaster Support, Dynamic Mobile Units Allocation, Mobile Space, Crisis Information Management

INTRODUCTION

In recent years, disaster support in Japan has increasingly incorporated mobile spatial units such as trailer houses and container-based units. Unlike conventional temporary housing constructed on-site, these mobile units are characterized by their mobility and relocatability in both normal and disaster conditions (Tsuchiya, 2019a; 2019b; 2021). This study aims to clarify the information requirements necessary for the rapid and efficient deployment of mobile spatial support and to propose a conceptual model for how such information should be managed and shared.

In Japan, temporary housing has traditionally been supplied under the Disaster Relief Act through on-site construction. Although the system assumes completion within 20 days after a disaster, large-scale disaster often require additional time due to land acquisition and infrastructure restoration, resulting in delays (MLIT, 2012). During the one to two months before temporary housing becomes available, public facilities such as school gymnasiums are commonly used as evacuation shelters. However, shelters do not always provide acceptable living conditions. Problems such as deterioration of sanitary environments, increased of chronic illnesses, and psychological stress have been reported (Suda, 2019). While life-saving operations are prioritized immediately after a disaster, maintaining acceptable quality of life in shelters is also important.

Mobile spatial units include housing units and off-grid sanitation facilities. These units have the potential to improve the quality of life in shelters during the early phase of a disaster. To maximize their effectiveness, an information infrastructure is required to support decisions concerning where, what type, and when such units should be deployed.

In Japan, various efforts have been undertaken to reduce fragmentation in disaster information management. A representative example is SIP4D (Shared Information Platform for Disaster Management), developed by the National Research Institute for Earth Science and Disaster Resilience (NIED). SIP4D serves as a hub-based platform that aggregates and shares disaster-related information, including damage reports, shelter status, road conditions, and lifeline disruptions, across ministries and local governments.

ISUT-SITE, operated by the Information Support Team (ISUT), provides a web-based GIS interface that visualizes information accumulated through SIP4D (Hanashima, 2023; Ise, 2022; Yoshimori, 2024). Together, these systems contribute to situational awareness at a wide-area scale and support inter-organizational coordination.

However, their primary function is the integration and visualization of macro-level damage and infrastructure information. They are not designed to directly link evacuee-level needs with the allocation and relocation of mobile units. As a result, while effective for broad situational overview, these systems provide limited support for the dynamic, resource-level decision-making required for mobile unit deployment. Addressing this gap is central to the present study.

In the medical field, EMIS (Emergency Medical Information System) is used to share information on hospital damage and patient acceptance capacity. In addition, D-TRACE (Disaster Trailers-containers-vehicles Registration and Coordination Engine) serves as a system that registers disaster support vehicles—including trailer houses, toilet units, and laundry units—in normal times so that local governments can search and reference them during emergencies. D-TRACE plays an important role in visualizing the mobile units that can be mobilized after a disaster.

However, these systems are designed by sector and function. SIP4D integrates large-scale damage information, EMIS focuses on medical institution capacity, and D-TRACE registers and searches disaster support vehicles. None of them directly connect evacuees' living needs with decisions regarding the allocation of dynamic resources. In other words, they are not fully suited to managing mobile spatial units whose location and use change over time. Related work in disaster information system has explored real-time data analysis using social media and related technologies (Imran, 2015; Osaragi, 2017; Palen et al., 2016; Turoff, 2004; Vieweg, 2010; Yin, 2015).

Yi et al. argue that integrated location-routing models are effective for logistics and medical resource allocation during disasters. However, these models primarily focus on the optimization of goods, vehicles, and medical resources, and do not address changes in evacuee conditions or transitions in living arrangements (Yi et al., 2007).

While platforms such as Ushahidi and Humanitarian OpenStreetMap support crisis mapping and information visualization, they lack dynamic resource matching functionality. Although Sahana Eden offers organizational-level logistics matching, it does not support pre-disaster registration of local dynamic resources or individual-level need-resource matching triggered by evacuee input (Humanitarian OpenStreetMap, n.d.; Sahana Eden, n.d.; Ushahidi, n.d.).

There is a substantial body of prior research on post-disaster temporary housing that has identified challenges related to temporary housing provision and proposed improvements (Félix et al., 2013; Johnson, 2007; Quarantelli, 1997).

Against this background, the purpose of this study is to examine how mobile spatial units were utilized during the 2024 Noto Peninsula Earthquake and to clarify the information requirements necessary for their effective deployment. Based on this analysis, the study proposes a conceptual information management model that links human needs with the allocation of dynamic resources. By designing an information architecture suitable for mobile support, the study presents a framework intended to enable more responsive and efficient deployment of mobile spatial units in disaster response.

The proposed system is a conceptual two-layer information management model that connects evacuee data with mobile unit data. In this conceptual model, affected individuals themselves input their own information, while vendors managing dynamic resources input the resource data. Municipal officials then oversee the allocation planning of dynamic resources based on the matched results of these two data layers. This enables the efficient allocation of limited dynamic resources, ultimately contributing to improvements in the quality of life of disaster-affected residents.

FIELDWORK ON MOBILE SPATIAL UNITS IN THE 2024 NOTO PENINSULA EARTHQUAKE

Figure 1. Trailer Houses Deployed in Suzu City

Figure 2. Container-Type Units Deployed in Shika Town

In this study, cases of mobile spatial units deployed in Suzu City and Shika Town—both of which suffered severe damage during the 2024 Noto Peninsula Earthquake that occurred on January 1, 2024—are presented. Field investigations in Suzu City were conducted from February 10 to 11, 2025, and those in Shika Town from November 17 to 18, 2025. The research was based primarily on on-site observations and interviews with relevant local government officials.

Semi-structured interviews were conducted with local government officials responsible for disaster response and welfare services in each municipality, including staff from the disaster management, welfare, and construction departments. Interview topics covered the types and quantities of mobile units deployed, temporal patterns of use, decision-making processes for unit deployment and reallocation, and challenges encountered in information management and inter-agency coordination. Field observations at each site complemented the interview data. The collected data were analyzed qualitatively, with key themes identified through systematic review of interview notes and observational records.

Two municipalities were selected based on the diversity of deployed mobile units. The cases include a wide range of dynamic resources, from small-scale units such as toilets and laundry facilities to trailer houses, container-based temporary housing, and community facilities. These cases provide representative insights into the use of dynamic resources in the Noto Peninsula Earthquake.

In the aftermath of the Noto Peninsula Earthquake, a wide range of mobile spatial units were introduced in addition to conventional prefabricated temporary housing. These included trailer houses and container-type units deployed across affected areas. Within the confirmed scope of this study, more than 50 trailer houses (Figure 1) and over 500 container-type units (Figure 2) were utilized. The findings indicate that mobile spatial units have emerged as a significant option in disaster response and recovery efforts.

In addition, container-type toilet units and chassis-mounted toilet trailers were installed in Suzu City. Four units were in operation from January through July during the initial phase following the disaster; however, at the time of the field survey, most were no longer in active use (Figures 3 and 4). It can be inferred that, as infrastructure restoration progressed, the need for off-grid sanitation units declined. Off-grid toilet systems have limited processing capacity, making accurate estimation of required usage volumes critical. In practice, however, usage frequency was not systematically monitored, and no information management framework was in place to optimize their deployment and operation. A container unit equipped with laundry facilities was also introduced, but it had been relocated by the time of the survey. These cases indicate that demand for mobile units varies significantly depending on the disaster phase.

Figure 3. Off-Grid Toilet Deployed at a Hotel in Suzu City

Figure 4. Off-Grid Toilet Deployed at La Porte Suzu

Figure 5. Trailer Houses Deployed in Shika Town

Figure 6. Interior of a Trailer House

Temporary housing units utilizing trailer houses were also confirmed in Shika Town (Figure 5). One month elapsed between the occurrence of the disaster and deployment of the units, followed by an additional two weeks before operations commenced. The additional time between installation and occupancy was due to construction work necessary to connect the trailer houses to water supply, sewage, and electricity infrastructure. Because damage to local water and sewage infrastructure at the installation site was relatively limited, the installation timeline was comparatively short in the context of temporary housing deployment following the 2024 Noto Peninsula Earthquake. Despite the relatively rapid provision of temporary housing, occupancy rates were not particularly high. One reason for this was the floor plan of the trailer houses. Although the institutional framework designated the units for four occupants, the layout consisted of a single-room configuration (Figure 6). While the sanitary facilities were separated, the living space comprised only one main room. Such a layout was suitable primarily for households consisting of a couple with two small children. The limited number of such households in the affected area is considered to have contributed to the lower occupancy rate. This case reveals a misalignment between institutional assumptions, unit specifications, and the actual needs of affected residents.

These cases demonstrate that patterns of use of mobile units change over time, and that some units may eventually become unnecessary. The decline in the use of mobile toilets and the mismatch between trailer house layouts and actual demand suggest that merely supplying dynamic resources is insufficient; continuous monitoring of usage conditions and evolving needs is required. Trailer houses may also be used at evacuation shelters such as schools without full infrastructure connection. In the investigated case, approximately one and a half months were required before operations commenced. During this period, the units could potentially have been used at shelters for vulnerable evacuees. If generators are available, electricity can be supplied through simple connections, allowing trailers to function as air-conditioned private rooms installed in schoolyards.

Although mobile units can be relocated within short time frames, maximizing their effectiveness requires continuous monitoring of usage status, occupancy rates, length of stay, and unit specifications. Their effectiveness lies not only in rapid deployability and mobility, but also in selecting appropriate functions and specifications according to disaster phases and enabling timely reallocation through coordinated information management.

While mobile units are becoming increasingly diverse, mechanisms for systematically capturing and coordinating these assets remain underdeveloped. These findings suggest the need to reconsider operational and information management approaches for mobile-unit-based disaster support.

CONCEPTUAL DESIGN OF A TWO-LAYER INFORMATION MANAGEMENT MODEL

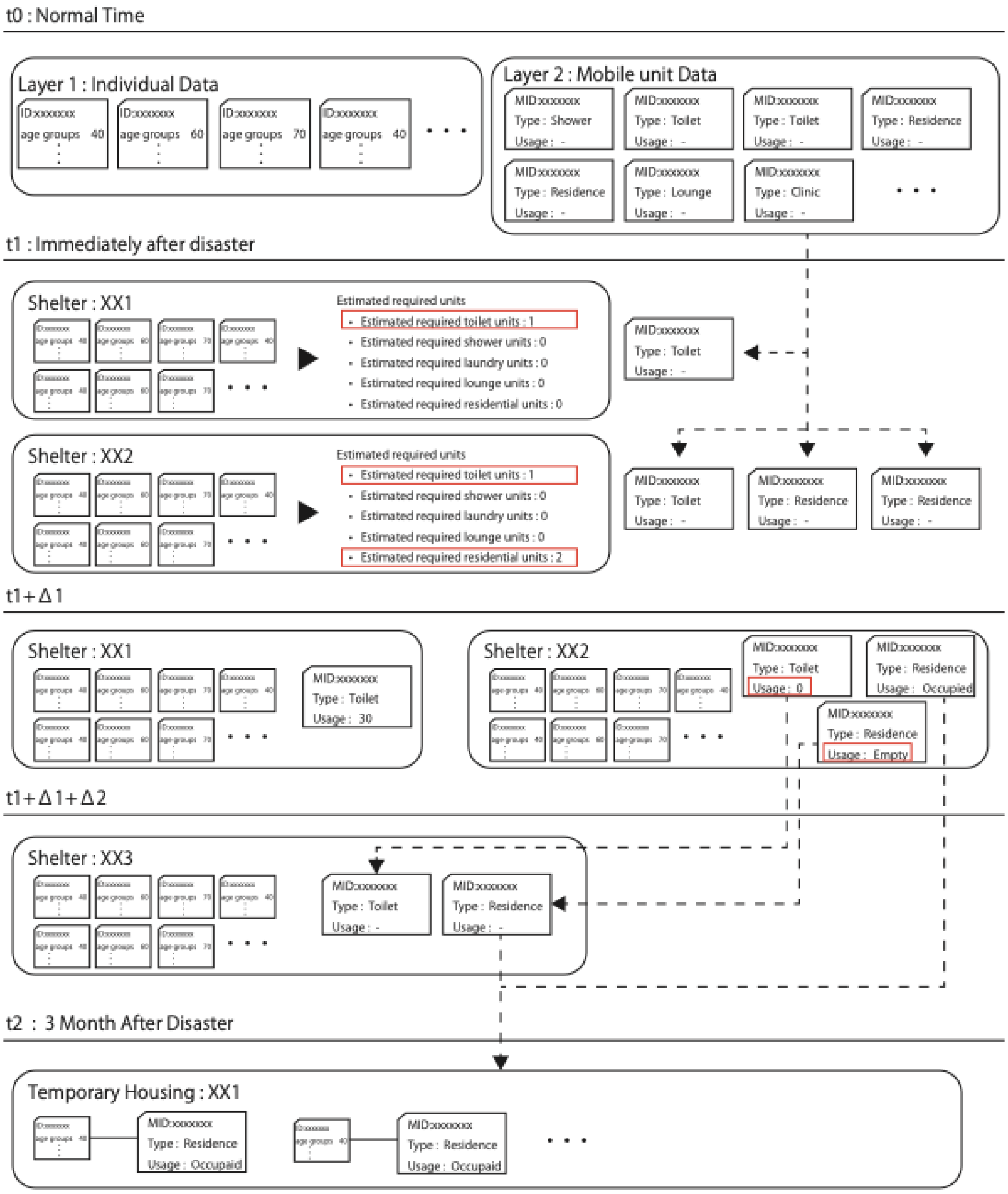

Figure 7. Diagram of Two-Layer Information Management Model

The fieldwork and interviews revealed two major challenges that directly motivated the design of the model proposed in this study. First, there was no systematic monitoring of unit usage levels or occupancy rates over time; once units were deployed, their utilization was not continuously tracked. Second, no mechanism existed to match evacuee characteristics—such as household composition, age profile, or medical needs—with the type and specifications of available units, leading to the mismatches observed in both municipalities. The conceptual model described in the following section was designed to address each of these gaps by linking individual-level evacuee data with mobile unit data through an aggregated coordination layer.

This study proposes a two-layer information management model to support the effective use of mobile units in disaster support (Figure.7). The model links information on affected people with information on mobile support units. In conventional disaster information systems, evacuees' health and vulnerability information has typically been managed separately from mobile resources such as toilets, laundry units, and trailer houses.

In recent years, however, support with using mobile space have become more common. As a result, two types of movement now occur at the same time: people move, and mobile resources move. After a disaster, affected residents may first remain at home, then relocate to shelters (At time t1), and later move again to temporary housing sites (At time t2). At the same time, support units are transported, installed, and relocated within the disaster area according to changing needs.

Because both people and resources move over time, it is no longer sufficient to manage them as independent datasets. Resource allocation must take these temporal changes into account. Without considering how needs and locations shift from one period to another, it is difficult to achieve appropriate and timely deployment of mobile support units.

In the proposed model, the first layer focuses on people and is organized around individuals. The information collected is intentionally limited to the minimum set of attributes required for support decisions. These include an anonymized identifier, age group, health risk status, level of care needed, household composition (including ages), pregnancy status, location, current place of residence (home, shelter, mobile housing, etc.), nationality, and whether pets are present.

A key point is that residence is not treated as a static record at a single moment in time. Instead, it is handled as a status that changes over time. For example, at time t1 immediately after the disaster, a person may remain at home. A few days later, the same person may relocate to a shelter. At time t2, the person may move again to a temporary housing site. By recording residence as a time series, it becomes possible to understand how living conditions evolve and how support needs change accordingly.

These individual records are linked to shelter-level information. At time t1, the system can identify how many people are present in each shelter and what their attribute composition looks like. This aggregated view functions as a needs profile for each shelter and forms the basis for subsequent allocation decisions. Based on this profile, the required unit types are estimated.

On the other hand, the mobile unit layer treats each unit as an independent management object. For each unit, information such as unit type, layout, installation location, operational status, and infrastructure connection is recorded in order to capture its condition as a dynamic resource. Unit types include showers, toilets, laundry units, kitchens, temporary clinics, housing units, and community spaces.

These units are managed within a supply-side. At time t1, shelter-level needs are matched against this unit data to determine appropriate allocations. Allocation is determined through a matching process between aggregated shelter needs and the available unit pool at time t1.

Each unit is equipped with tools such as GPS loggers to track location and sensors to measure usage levels. This makes it possible to identify, at time t1+Δ1, where each unit is located and how intensively it is being used. At time t1+Δ1+Δ2, usage patterns may change, and relocation to another site may become necessary. In this way, unit-related information is also handled as time-dependent data that is continuously updated along a temporal axis. At time t2, information such as household composition may enable the provision of housing units with more appropriate layouts.

The two layers are connected through an aggregated linkage layer. At time t1, individual-level information is aggregated at the shelter level. Specifically, the data are converted into total counts by attribute, indicating how many people with particular characteristics are present in each shelter. From this process, shelter-specific needs—such as the number of elderly residents or medically dependent individuals—are derived. By comparing these aggregated needs with the unit data, appropriate resource allocation becomes possible.

For example, the number of housing units required can be estimated based on the number of households with infants and the number of medically dependent individuals. Shelters with many children may be assigned community-space trailers, while housing units can be transported for medically dependent residents. In this scenario, the units do not rely on local infrastructure. Instead, they use generators to provide electricity and air conditioning.

Because the unit layer also records operational status, usage levels can be monitored. Units with high utilization may justify additional deployment, while those with declining usage can be relocated. For instance, housing or community units with reduced occupancy in shelters may be moved to another shelter.

Data input and maintenance for the proposed information system is assumed to be handled primarily by municipal officials. It is assumed that affected individuals input basic information during normal times, and during a disaster, input only the data about the evacuation site where they are staying. By minimizing the data required to be entered during the chaotic period immediately after a disaster, the burden on affected residents is reduced. In Japan, municipalities and companies that manage dynamic resources input their data during normal times. Municipal officials then review the matching results between evacuee data and dynamic resource data and make decisions on resource deployment. The matching process works as follows: the system first cross-references the type, quantity, and priority of necessary resources entered by evacuees at shelters against the type, quantity, and location of dynamic resources registered in advance by municipalities and companies. During the matching, resource candidates that can fulfill the needs are ranked by priority, based on geographic proximity between the shelter and the resource location and the correspondence between supply and demand. Municipal officials review this ranked list and make the final deployment decision, incorporating contextual judgments such as road conditions and coordination with other shelters. The system is designed to present candidates only, without issuing automatic deployment instructions, thereby ensuring that human judgment by officials is maintained.

In this model, privacy protection is embedded as a fundamental design principle. Individual-level data uses anonymized identifiers, and no directly identifiable personal information such as names or addresses is included. The data used for mobile unit allocation decisions is aggregated at the shelter level into attribute-specific counts (e.g., number of elderly residents, number of medically dependent individuals), so that individual data is not directly shared with resource allocation decision-makers. Regarding access control, a hierarchical permission structure is envisioned in which access to the individual data layer is restricted to welfare and medical personnel, while the aggregated data layer is also accessible to logistics coordinators.

Mobile support is characterized by its mobility. To maximize its effectiveness, however, information management must reflect temporal change. Real-time updates at the level of seconds are not required; updating the data every half day or once per day is sufficient. This model is referred to as the Dynamic Unit Allocation Framework, an information management approach designed for mobile disaster support.

Discussion

In current disaster response practices using mobile resources, smaller units tend to be actively deployed and relocated in the early phase of a disaster (t1). In the mid-term phase (t2), larger residential units that require connection to infrastructure are more commonly used.

However, with appropriate information management, residential units could also be deployed during the early phase without relying on local infrastructure. When powered by generators, they can provide climate-controlled housing units for vulnerable populations.

The proposed information system is designed to be implemented as an application. Individuals would input their basic information during normal times, and companies or private owners of mobile resources would also register their available units in advance. With such preparation, residential and other mobile units could be prioritized and deployed to shelters where a large number of vulnerable people are present. This may help reduce health risks and secondary damage after a disaster.

The system proposed in this study—match between individuals and mobile resources—may be used not only during disasters but also in normal times. For example, individual data could support home-care services for people requiring assistance or help monitor conditions within local communities.

Mobile resources could also be used for public events, such as deploying toilet units at large gatherings or shower units at beaches during the summer season. Collecting operational data during such routine uses would contribute to maintenance planning and could also function as a form of practical preparedness exercise for disaster situations.

In Japan, where disasters occur frequently, multiple information management systems have been developed for emergency response. In this context, it is important for users to become familiar with such systems during normal times, rather than encountering them for the first time during a disaster.

CONCLUSION

This study analyzed the use of mobile units during the 2024 Noto Peninsula Earthquake and identified changes in needs across disaster phases as well as challenges in information management. Existing disaster information infrastructures are typically designed by sector and based on fixed facilities, and therefore do not adequately reflect the dynamic characteristics of mobile support. In response, this study proposed a conceptual model that manages human data and unit data in two layers and links them through an aggregation mechanism. The model demonstrates the potential to build an information architecture that improves the allocation of mobile units while taking into account data protection and institutional constraints.

Several challenges remain for implementation. First, communication infrastructure may be disrupted during large-scale disasters. Mobile and fixed networks are likely to be unstable or unavailable, and cloud-dependent systems may fail under such conditions. The system must therefore be designed for intermittent connectivity, incorporating offline input functions, local data storage, and delayed synchronization. This is particularly important because mobile units are often deployed in heavily affected areas where communication is unreliable.

In addition, if implemented as an application, the system must provide a user interface that is accessible across age groups and usable in both normal and disaster situations. Future research should address these issues in order to develop the conceptual model into a practical and implementable framework.

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