

# Research on the Spatial Layout of Emergency Product Vending Machines from the Perspective of Resilient Cities—Taking the “Emergency Box Dimensional Cabin” as an Example

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**Abstract:** In view of the current research situation about the construction of resilient cities, the timeliness, balance and sustainability of urban emergency supply are very important. This paper mainly studies the “Ji Box Dimensional Cabin” intelligent emergency service station, combining the development situation of vending machines all over the world and the actual problem that there is a lack of emergency commodity supply in China, based on spatial layout theory, evaluation criteria, mathematical programming formulations, solution approaches: In this regard, an overview structure of studies is proposed to achieve balance between disaster response, scenario adaptation ability, and operation in a commercial environment. The model can theoretically guide and practically optimize the robustness of the city emergency services system and the location planning of public services terminal facilities.

**Keywords:** Resilient city; Emergency supplies; Vending machines; Spatial layout

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## 1. Introduction

The operational risk of cities has become more complicated these days; it is important to build up an effective and stable emergency supply system to enhance the city’s resilience. The advantages of emergency vending machines include flexible deployment, quick action, and around-the-clock operation, actually filling up the blanks in coverage by conventional emergency supply stations. Now, domestic vending machines usually face problems such as uniformity of products provided, no special items for emergencies, low situation adaptability, etc., and a small-profit model, which can’t meet the needs of the emergency service of the resilient city. In this article, we use “Ji Box Dimensional Cabin” as an object to study the layout planning method of the emergency vending machine in a systematic way.

## **2. Theoretical basis for the layout of emergency vending machines from the perspective of resilient cities**

### **2.1. Requirements for spatial equity and coverage efficiency of urban emergency services**

The spatial fairness of urban emergency services means that every area or population in the city can obtain equal, convenient emergency resources, avoiding service blind spots and/or imbalances due to over-concentration of resources, and in accordance with the requirements for building resilient cities, emergency service facilities shall be designed to ensure adequate coverage for priority zones, including high population density areas, universities or colleges, transport nodes, in order to satisfy the minimum requirements during an emergency situation by the most vulnerable population segment (i.e., senior citizens, students, and migrants). On the other hand, for layout design, we want good global coverage (maximizing the area covered with the least number of devices), minimizing the waste of resources due to unnecessary duplication, and providing timely assistance to people who may be affected by a disaster.

Spatial fairness interacts with coverage effectiveness, so that we need to move away from isolated emergency vending machines toward connected, planned placement. Through the rational design of the coverage radius for services, as well as the uniformity in terms of the number of terminals placed in each area, coverage with no gaps and holes in the entire city area is ensured. The deployment plans of different scenarios, such as commercial buildings, tourist attractions, and neighborhoods, not only to guarantee general and equal access to emergency assistance but also for the efficient use of facilities.

This layout pattern can help to maintain the stable supply of materials for city emergency relief and achieve relatively equal, efficient and sustainable emergency services in order to provide the basis of a resilient city.

### **2.2. Spatiotemporal patterns of emergency supply requirements and determinants of their spatial configuration**

The needs of emergency supplies have obvious space-time characteristics and show large differences in each period, season, and scenario. The campus and office area have a high demand concentration in the daytime, but the community and transport hub have more demands at night and on holidays. During special periods like the rainy season, the demand for emergency materials is significantly increased. flu season, and travel peak. This temporal change has a direct impact on the choice of location, products to be sold, and replenishment strategy, which reflect key concerns of land use planners. If such variations are not taken into account, there is the potential for overdevelopment and underdevelopment.

The features that influence the placement of emergency vending machines are complicated and varied, but mainly include population density, scenario type, transportability, accessibility, operation & maintenance cost, and profits. Shopping malls and tourist places have large footfalls with scattered emergency demands; campuses and dormitories have the characteristics of stable demand and explicit demands on category products, but stations tend to pursue fast delivery and mobile supply <sup>[1]</sup>.

### **2.3. The mechanism of multifunctional composite terminals in enhancing urban resilience**

The multifunctional integrated emergency terminal that combines the functions of emergency supplies, IP-based cultural products, and self-service printing: enhances equipment utilization and revenue level, avoids service interruption due to loss of operation, and provides consistent and reliable emergency supplies. This “commercial operations supporting public services” model removes the dependency on one source of income from emergency facilities, giving them more risk resilience.

The integrated terminal can also realize the deep integration of emergency service and normal service, forming a combined operation mode for normal service and emergency service. In the normal period, the equipment meets day-to-day usage requirements and public printing demands; if needed, it could quickly be deployed to serve as an area of immediate emergency stockpiling, providing emergency services, e.g., first-aid kits or temporary equipment.

### **3. Evaluation index system for the layout of emergency commodity vending machines**

#### **3.1. Population density and key scenario spatial demand identification indicators**

Emergency Demand Scale: The main index is population density. Areas where both permanent and migrant populations are large have a great demand for emergency materials and need to respond quickly; thus, it is more important to install emergency selling kiosks in these areas. We may also derive other indicators from our main one, like maximum crowd density, daily fluctuations in traffic flow, and demographics. Numerical information allows for measuring travel demand levels at a particular area, controlling the distribution of equipment number and size. The places that have obvious crowd gathering features, such as campuses, shopping centers, public transport nodes, etc., should be considered as separate entities in the demand retrieval process.

The main scenario-based spatial demand parameters highlight that the greatest level of synergy exists between equipment functionality and individual scenario needs; commercial zones are optimally provided by combining emergency stock and IP-based goods; campuses need more emergency medication, paper products, and printing; communities have an interest in household emergency supplies; while the shelters are supposed to be prepared with portable first-aid kits. Based on differentiating the situations, a weight for each situation can be assigned, as high-value locations are precisely identified to increase the accuracy of resource allocation and prevent ineffective utilization due to random distribution. The scientific demand identification makes emergency service closer to reality, thus leading to higher configuration efficiency in general.

#### **3.2. Quantitative standards for transportation accessibility and emergency response timeliness**

Transport accessibility indices reflect ease of users' access to amenities and effectiveness in the delivery of emergency supplies, mainly including the travel distance within walking range, road connection situation, coverage of public transportation, and logistics access conditions. Good transport accessibility can effectively shorten the time for emergency rescue operations and improve the effectiveness in purchasing supplies, especially in cases of partial traffic disruption caused by disasters, wherein the superiority of facility location based on distance will be more obvious. The service time for a certain number of residents (usually 5–10 min) is usually used as the service range.

The quantitative criterion of promptness in emergency relief is the time it takes to acquire materials and goods during an emergency, setting the target threshold according to urban public security rules. Users need to get emergency supplies in a timely manner within 10 min for ordinary cases, while waiting time during congestion periods should also be improved. Based on the accessibility analysis and timeliness simulation, service-deficient regions can be determined and supplemented to form an efficient emergency service system promptly; reasonable scientific timeliness requirements are put forward, which improve the ability of cities to respond to emergencies and enhance their security defense capacity.

#### **3.3. Evaluation dimensions for operational feasibility and scenario function compatibility**

The technical and economic analysis is based mainly on the cost of sites, electric power lines, difficulty in replenishment capability, ease of access (stable power supply and network connectivity for equipment installation and routine maintenance), and profitability. High logistics accessibility lowers the cost of replenishment, reasonable passenger flow, and product mix guarantees basic profits. The operability will determine if the terminal can run steadily in the long run, which is the key limitation to project deployment, and also the basic premise of its viability<sup>[2]</sup>.

Scenario-Function Fit: The fit of functions to scenarios is also good in that there are many functions for devices that match particular situations (e.g., in offices and campuses, printing services are given priority; the IP-branded cooperative products are emphasized in shopping malls and scenic spots; while at housing sites or transit stops, more specific attention is given to emergency supplies. The higher the degree of congruence, the higher will be the rate of utilization by residents and users, realizing the optimal coordination of the emergency function with the business operation. In terms of multi-dimensional integrated evaluation, the best positions where both urgency and practicality are considered so as to improve the plan quality.

## **4. Spatial layout model and optimization method for the “emergency box dimensional cabin”**

### **4.1. Initial point selection and classification rules based on multi-scenario differences**

The first stage of the location choice is determined by the city’s functional scenario, and it focuses on areas like commercial buildings, such as tourist sites, universities, metro stations, and big neighborhoods. We perform a first evaluation through the analysis of population density<sup>[3]</sup>, emergency response needs, and site situation. In this screening phase, sites that have unreliable electricity, weak signal strength, inconvenient access, or great operating difficulty are intentionally avoided in order to achieve the purpose of normal and stable equipment use for a long time as well as the maintenance capability of services. Differed classification standards according to the characteristics of scenarios: shopping centers, tourist attractions, focus on passenger flow and consumption ability; campuses and communities highlight emergency livelihood services and basic service coverage; whereas transport hubs emphasize fast response and convenience of accessibility, which can choose locations more focused, reasonable, and realistic.

In the context of multi-scenarios classification scheme, another hierarchical accessibility strategy is adopted for improving the scientific level of the whole layout again: The first-tier service facilities are located in regions where emergencies happen frequently (campuses, communities, subway stations etc., emphasizing full basic services coverage and fast response capability; second-tier points located at places with large crowd flow, such as shopping malls and scenic spots, which have a more diffused demand for emergency services, but also for customer access. The third level is used to complement the first two levels with offices and leisure facilities, forming a tiered, layered, and hierarchical service network; the classification can avoid excessive concentration of resources and waste, and minimize the gap between services, so as to lay the groundwork for later accurate demand prediction and effective space allocation.

### **4.2. Location calculation with dual orientation for emergency needs and IP consumption**

Based on the scale of emergency demand as the main basis index and combining multi-dimensional information such as regional population density, age distribution, and diurnal flow fluctuations, the location calculation is carried out. The statistical models used for predicting the number of emergency supplies consumed as well as peak load demands in the emergency period are given by allowing for a science-based definition of the best possible service radius per device, and of how many devices are needed to be deployed in an area; dynamic factors (such as seasonal variations, diurnal variation, and special days) are introduced for continuous refinement and optimization of the demand curve so that the results have higher accuracy and operability without over-deploying sites or under-providing emergency supplies caused by fixed estimation. The whole calculation takes into account the fact that emergency supply coverage is very low when it comes to scenes like campus and community, appropriately increasing deployment density in key public service areas.

As a second axis of analysis is the so-called IP consumption potential, which mainly includes an analysis of consumption preference in highly Generation Z-concentrated scenarios and by looking at the demand for IP co-branded products: popular items, and self-serve print stations, to analyze each site’s market viability and sustainability, thus reconciling the public welfare aspect of emergency service with project sustainability<sup>[3]</sup>. For commercial and traffic-oriented scenarios, the weight of IP products will be properly increased, so as to increase their attractiveness and profit margin; in the community campus, the focus lies on emergency function and aims to achieve an overall balance between “satisfying the basic emergency needs and making full use of culture’s creative potential as value-added”. Such a two-way assessment will ensure that the location plan can meet both the demand for building a resilient city and guarantee steady profitability, substantially increasing the overall viability of that endeavor.

### **4.3. Layout decision that balances coverage equilibrium and operational efficiency**

The placement selection is performed using a multiple objective optimization approach where the main objectives are uniform distribution of space, fast emergency response time, controllable operating cost, as well as steady total return.

We conduct multi-dimensional weighted scoring and overall sorting for candidate sites. And we balance the coverage of service in the whole region. The model selects good sites that are characterized by a high level of demand intensity, ease of O&M, and high commercial value. Thus, it can avoid blind development and waste of resources.

A self-adjusting algorithm in the deployment phase aims at optimizing the whole topology according to new running information dynamically. The high-load, high-return, and high-demand locations are densified for higher service capacity, whereas low-traffic, low-efficiency, and low-demand locations are relocated or removed from operations in order to reduce operating costs, maintaining proportionality such that the design is responsive to changing city space and demand requirements. The trade-off between coverage equity and system performance, on one hand, provides a guarantee for even distribution of service response time, while, on the other, enables steady state reliable functioning over extended periods in the terminal infrastructure. Thus, the “Ji Box Dimension Cabin” will be a stable and sustainable public emergency supply node in resilient cities, which can greatly improve the overall safety assurance capability of the city.

## **5. Implementation of emergency vending machine layouts and strategies for enhancing urban resilience**

### **5.1. Construction of a comprehensive, hierarchical emergency service terminal network**

The whole hierarchy network distributes emergency selling outlets in terms of three levels, including the city center region, district centers, and residential points. The dense deployment of the center area with more terminal densities to achieve complete coverage constitutes a service system with higher density, speed of delivery, and a wide coverage area. District hubs serve the purpose of filling in holes and serving local disaster relief material distribution and transfer needs. Resident areas/campuses set up simple stations according to actual conditions to achieve some simple disaster relief services and normal business purposes. In different levels, data exchange, and integrated scheduling to create an integrated terminal network with a common control, decentralized supply, and local response capability that greatly enhances the ability of the city to withstand and recover quickly from emergencies.

Based on the hierarchical networking, the “main station + auxiliary points” mode is used for optimization of space pattern. Main stations can be set up in key places like transportation hubs or business districts, with complete emergency equipment, IP culture and creativity products, self-service printing equipment, serving integrated service function; auxiliary points are deployed in an efficient way inside the community, building, and industrial park areas, in terms of providing basic emergency materials. Such a combined layout method can eliminate service dead zones to a certain extent, which also controls building cost and operation cost rationally; moving emergency response from an ad hoc, localized system of emergency responders to a coordinated, interconnected, standardized system, thus offering a constant and stable supply of material security to the city’s peace and order<sup>[4]</sup>.

### **5.2. Layout adjustment and operations mechanism driven by dynamic demand**

The dynamic demand-oriented model takes into account crowd flow detection, consumption information, seasons, and emergency warning messages to monitor in time the space-time characteristics of emergency material requirements, allowing for regular re-optimization of the equipment location/product mix/service function during high influenza seasons, rainy days, and holidays, rapidly boosts reserves and diversity of emergency supplies; during the school-year and workday rush hours, it improves printing services and replenishment of daily consumption supplies, making the terminal supply system as close to real needs as possible and improving the utilization rate of resources and the accuracy of services.

In terms of operation and maintenance, we have built a smart schedule and standard management platform, which will use artificial intelligence prediction models to calculate the rate of product consumption as well as its change trend. The system automatically generates a scientific replenishment plan and optimized delivery route, thus reducing labor, logistics, and the cost of time. Moreover, standardized maintenance practices, such as periodic equipment checks, rapid fault reporting and repair, and timely update of data, are implemented to guarantee the steady operation of equipment in the long run.

### 5.3. Business models and sustainable operations under the integration of composite functions

The multi-functional business model takes the emergency supply as the main source of traffic driving, uses the IP culture and creativity products to increase the possibility of high price positioning and product attractiveness, and uses self-service print services as a means for increasing users' loyalty and utilization. This generates a diversified, high-margin, and robust profit model, which can solve the pain points in this field, like low profitability of conventional vending machines, extreme standardisation of products, and lack of sustainability. Emergency role guarantees public service characteristics and social worth, while the IP and the printing operation add commercial and operating efficiencies. The two parts serve to reinforce one another.

The third is technology support and templates. Through the means of smart card payments, inventory control systems, and end-user activity monitoring, operational effectiveness and control accuracy are improved. A light-weight, modular construction lowers installation cost and facilitates expansion to additional sites. Once a site has reached full scale, a replicable, scalable, and stable standard model is gradually formed, covering more cities and scenes; a stable and sustainable business model can make the operation of emergency terminals not affected by operational problems, supporting everyday, sustained, high-volume disaster response activities, which reinforce the general resilience of urban areas to hazards and their ability to recover quickly from them.

## 6. Conclusion

On the premise of anti-disaster city construction, it is an effective way to improve the ability of city emergency response through the scientific layout of emergency vending machines, and the "Ji Box Dimension Cabin" can solve the problem of lack of emergency supplies, product homogeneity, and weak profitability of domestic vending machines with the combined design of emergency supplies, IP-based culture products, and self-service print function. It needs to fully take into account factors such as population density in its space planning, usage patterns, traffic flows, and service demands for an integrated, optimal, and adaptive hub system.

## Disclosure statement

The authors declare no conflict of interest.

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