Application of System Thinking and Factors Interrelationship Analysis to Identify Primary Success Factors of Post-Natural Disaster Recovery Projects

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Abstract: An increasing number of natural disasters and deficiencies in recovery projects have emerged recently and necessitated the creation of versatile guidelines to achieve successful Post-Natural Disaster Recovery (PNDR) projects. Although some criteria have been set to measure these PNDR projects’ success, this topic needs further investigation. The solution may be extensive studies offering a holistic explanation for PNDR projects’ success. This paper creates a comprehensive continual cycle to illustrate these projects’ objectives. Subsequently, subsets or influential elements of the defined objectives can be recognized. Recently, several attempts have been made to apply System Thinking to construct a framework of the influential factors in a successful PNDR project; however, there is little focus in the previous works on identifying all the influential elements. This study can be separated into two parts; the first involves context analysis, which is applied to numerous resources coded by NVivo 2020 and several codes derived from five subsystems. Subsequently, the identified factors within the PNDR projects’ life cycle are analyzed twice, and the existing interrelationships are found out. The factors’ redundancy is examined, and among the 59 final factors, an objective-based categorization is performed. The time-based objectives, known as Primary Success Factors (PSFs), and their subsets/influential parameters are lastly illustrated and used to structure the identification and measurement of Critical Success Factors (CSFs) for future research.

Keywords: recovery after natural disasters; successful project management; life-cycle; NVivo

1. Introduction

The occurrence of natural disasters threatens cities’ facilities and leads to massive destruction. People suffer from the devastating effects of natural hazards. The multilateral topics addressed in PNDR projects involve countless stakeholders, leading to the arising of different demands, experiences, and knowledge [1–3]. Moreover, the necessity of coordination, the multiplicity of objectives, and the difficulties of effective project management are the principal sources of the complexity of PNDR projects [4]. Limited resources and the different desires of the beneficiaries [5,6] force PNDR project managers to find the most effective management method. In the last two decades, various studies have addressed several subjects in this area. The frequencies of the different studied topics in the research literature are shown in Figure 1. Although some focused on one major, integrated research attempting to see PNDR projects as a system and discussing a raft of issues is also common. Enshassi, Chatat, Meding, and Forino [7] attempted to identify the factors affecting post-disaster reconstruction project management for housing from the perspective of governments and the involved organizations. However, public well-being and people’s satisfaction were not considered in their research. In another research study conducted by Meding, Oyedele, and Bruen [8], the recognition of barriers in post-disaster reconstruction projects alongside the competence clusters of these projects led to the identification of the success indicators of post-disaster reconstruction projects. However, the suggested model’s
effectiveness and the subsequent indicators require further study. On the other hand, to measure the success of PNDR projects, the terms “Key Performance Indicator (KPI)”, “Selected Success Factor (SSF)”, and “Critical Success Factor (CFS)” have been interchangeably used in some studies. Didem Gunes Yilmaz, and Jason Von Meding [9] differentiated these indicators, and showed their interrelationship. Following their definition of these criteria, SSFs are necessary to forming CSFs, which lead to project success. Once the CSFs have been formed, the KPIs can be constructed to evaluate the PNDR projects’ success. CSFs have been traditionally classified according to time, cost, quality, and stakeholders’ desires [3,10]; however, some modifications are necessary to make the evaluation criteria appropriate for evaluating PNDR projects.

![Figure 1. Mentioned subjects in the research literature review.](image)

To form strategies to successfully manage PNDR projects, these projects should be seen as multidimensional subjects, the success of which relies on the progress of subgroups. Additionally, most of the recovery projects after natural disasters are simplified as reconstruction projects. The last two mentioned facts indicate the urgent need to manage recovery projects comprehensively and successfully after natural disasters. This subject constitutes a new domain with largely unstudied potential. To rescue these topics from obscurity and design successful PNDR projects, the projects’ objectives should be defined. Although some attempts have been made to address this issue, such studies usually measure the PNDR project’s success via the “evaluation” or “assessment” of the project’s outcomes [11], and there is a lack of clarity due to the absence of a clear definition of the success of PNDR projects.

This study identified Primary Success Factors (PSFs) via a review of several resources that focused on post-natural disaster recovery projects and were published in the period 2002–2020. The application of System Thinking has helped categorize the influential factors in PNDR projects’ successes. In addition, the time at which the assessment is conducted is as important as the other criteria evaluating the success of PNDR projects [12]. By applying a method factor interrelationship analysis based on the project’s life cycle, the influential factors have been assessed for to check redundancy and to reduce their numbers. The interrelationships among the influential factors were used to detect the PNDR projects’ primary goals (known as PSFs) and their subsets. This study’s result is the basis for the next phase, which is part of a broader project aiming to set an Evaluation Index System for PNDR projects.
2. Materials and Methods

The research methodology attempting to identify influential success factors in PNDR projects follows a four-step process: context analysis, System Thinking, life-time study, and factor interrelationship analysis. This methodology is schematically shown in Figure 2. Moreover, the process of the refinement of the influential factors and the identification of the PNDR projects’ objectives is shown in Figure 2.

- Context analysis: To commence the study, the researchers selected English academic resources, including papers, manuscripts, books, and dissertations, that had been published from 2002 to 2020. “Post-Natural Disaster Recovery”, “post-disaster reconstruction”, and “natural disasters” were the keywords used to select the academic resources. The resources selected and stored in Mendeley have been read twice, and the cited influential factors were extracted (Figure 3). Figure 1 represents the common topics that arose in research context analysis.

- System Thinking: Considering systems as nonlinear and dynamic feedback loops containing a group of elements related to one another and their environment, Systems Thinking aspires to take a broader view of the issue as a whole [13,14]. Traditional thinking methods break a project into parts and neglect interrelationships, while System Thinking attempts to track patterns of changes [13]. System theory incorporates the principles, models, and laws intrinsic to the interrelationships and interdependencies between the components of a complex system [13]. PNDR projects can be seen as systems that consist of numerous components. These projects are influenced by a complex environment causing myriad difficulties that make the control of the recovery project a tough job [15]. As shown by the context analysis, the use of System Thinking in PNDR projects is prevalent [14,16]. As such, System Thinking, which involves “seeing the forest for the trees” [13], was applied in this research to expand our understanding of the intricate nature of PNDR projects. Through the application of System Thinking, five sub-systems, 16 groups and 73 factors influencing PNDR projects’ success have been coded by NVivo 2020. Their frequencies were then analyzed based on the literature review.

- Life-time-based study: PNDR projects involve continuous procedures that may continue for several years. To identify the final objectives of the PNDR projects, an appropriate life cycle for these projects should be determined. This study’s suggested life-time framework considers the activities required to successfully manage PNDR projects within a continual life cycle.

- Factors interrelationship analysis: Two rounds of factor-interrelationship analysis were conducted to determine the extracted influential factors’ accuracy and redun-
dancy. This process can also simplify the data collection and calculation processes of future studies that will be conducted in this area. The influential factors were assessed throughout the continuous life cycles of PNDR projects. Finally, their number was reduced to 59, and the time-based objectives of PNDR projects, called PSFs, have been rendered.

Figure 3. The 85 factors identified from the context analysis.

3. Results

3.1. Influential Factors Based on Context Analysis

Not only should the recovery projects after natural disasters focus on rebuilding and improving buildings, but the recovery of the business and community structures should also be considered [17]. As seen in Figure 3, the 85 relevant factors have been placed in five sub-systems based on the topics mentioned in the literature review. This catego-
rization process endeavored to address the majority of the common concerns arising in PNDR projects.

3.2. Influential Factors Based on System Thinking Application and Codification: Sub-Systems, Groups, and Factors

A consideration of the branches of the system is essential to fully utilizing the concept of System Thinking. This paper presents a new method of comprehensively depicting the factors affecting PNDR projects’ success. Via the application of System Thinking and according to the research’s literature review, the researchers proposed the following framework. Considering PNDR projects as a system, five sub-systems have been identified. These subsystems, which are the main branches of this framework, incorporate the multidimensional aspects influencing PNDR projects. Subsequently, the groups arising from the establishment of the sub-systems have been addressed. The groups indicate the influencing factors and place each factor in an appropriate position. Finally, 73 factors affecting PNDR project progress were codified by NVivo 2020. Evidently, the use of System Thinking, especially in the grouping section, enables the researchers to make sure not leaving any influential factor out. The System Thinking framework is demonstrated graphically in Figure 4.

**Figure 4.** PNDR project’s components as a system.

3.2.1. Social Sub-System

As the users of urban facilities, people are the main victims of the unsafe conditions, fragile structures, and inadequate services left by natural disaster. Several authors have studied the necessity of recovering people’s living conditions. On the other hand, people’s participation in the recovery process might bring acceptable recovery outcomes. The role of people, varying from consultation in decision-making to participation in the construction phase, is undeniable. The context analysis shows that a large body of work has been undertaken using the most frequently mentioned keywords, shown in Figure 5. “Participation”, “community”, “public”, “social”, “people”, and “training” are the terms discussed most frequently. Moreover, people’s livelihoods, safety, culture, and needs have been widely considered in the reviewed literature.

Active community participation, from decision-making to the reconstruction stage, must be appropriately managed [3,15,17]. Additionally, the marginalization of certain people, such as women or ethnic groups, will cause future difficulties [18,19]. Previous studies have partly addressed this problem, such as those by Zhao, Taucer, and Rossetto [20], suggesting the simultaneous engagement of representatives from all the affected groups identified. Moreover, the necessity of informing the community of the PNDR process has been emphasized by Tauber and Platt [21,22]. Low public awareness (knowledge) of hazard prevention and safe structures can cause further danger [16,22,23]; thus, raising public awareness about safe structures and disaster prevention through training, workshops and meetings should be considered [21,24].
Economic improvement, frequently addressed as “improved livelihood”, is another key concept. Providing job opportunities for the affected people has been suggested as the most significant means of attaining the betterment of livelihood [19, 25]. In this sense, hiring local people instead of outsourcing a workforce is preferred [19]. In order to tackle financial barriers, the establishment of an assistance system is another proposed solution. Financial assistance and long-term payback plans for loans are two of the recommended solutions; however, financial assistance should be designed carefully so as to avoid people depending on external help [25, 26]. Moreover, livelihood recovery should be planned based on sustainability so as to form a sustainable livelihood structure that enables the community to resist sudden changes [27].

Moreover, communication among people and decision-makers is another difficult issue [28, 29]. Improved and effective communication throughout natural disaster recovery projects enables a better flow of information and the easier identification of the stakeholders’ real needs [15]. Figure 6 illustrates the frequency of the social factors that arise, and the most critical components are highlighted. The most frequently mentioned factors are “Significant level of community participation”, “Increasing public awareness for the prevention of hazards”, “Recovery of livelihood”, and “Effective and holistic communication system”.

Figure 5. The frequently mentioned keywords in the social sub-system, based on the context analysis.

Figure 6. Frequency of factors in the social sub-system.
3.2.2. Economy Sub-System

Although financial management plays a significant role in all sorts of construction projects, the financial challenges may be greater in PNDR projects due to time limitations and public pressure. The keywords presented in Figure 7 contribute to a word cloud depicting the economy sub-system’s most influencing factors. “Land”, “funding”, “economic recovery”, “property rights” and “fund allocation” appear frequently.

Figure 7. The commonly mentioned keywords in the economy sub-system based on context analysis.

Bearing in mind that funding is one of the most important stages in financial management, many PNDR projects suffer from insufficient funds [15]. The shortage of financial assistance affects the project’s progress; furthermore, the residents’ life may be affected negatively [29]. The lack of long-term recovery plans also highlights another forgotten topic that must be addressed [30]. Given the importance of the time and resource limitations faced by PNDR projects, rapid and fair fund allocation is key to the project’s success [30–32]. Additionally, donor resources should be adequately managed [29]. The pre-planning of resource allocation has been recommended by Kermanshachi, Bergstrand, and Rouhanizadeh [32] so as to prevent time-wasting and the occurrence of errors.

On the other hand, in the aftermath of disasters involving massive damage to physical structures, properties’ ambiguous ownership status is particularly burdensome [7,29]. The establishment of property rights, both for private and non-private individuals, offers important protection [33,34]. Apart from the protection of ownership rights, another factor commonly explored in previous studies is the recovery of local businesses [18,33,35]. With a revitalizing and strengthening business plan for the affected area, the residents’ livelihoods can recover quickly, and even improve. Hiring local people, thus generating job opportunities for the residents, is one practical solution leading to the fast recovery of livelihoods [19,25]. It should be noted that an area’s unique characteristics must be considered under long-term economic development plans [36,37]. Figure 8 indicates the most important influential factors in the economy sub-system. “Economy development plan based on area’s distinctive features”, “Private and non-private property right protection”, and “Sufficient funding availability” are the three most influential factors within the economy sub-system.
3.2.3. Environment Sub-System

Recent years have seen a rise in the number of studies exploring sustainable environment and its impacts on human life. This research study intends to consider the natural environment as well as built structures within the environment sub-system. Following the context analysis, “environment”, “structures”, “buildings”, “infrastructures”, and “maintenance” have been recorded as the most emphasized topics. However, “prediction and preparedness”, “retrofit and repair”, “prediction of secondary disasters”, and “early warning systems” are the other research concerns (Figure 9).

The real-time monitoring of environmental changes and recording the most recent natural disasters are considered helpful methods for predicting imminent natural disasters [16,37,38]. Real-time monitoring, which should be initiated before a disaster, must continue after the disaster in order to monitor the possibility of secondary disasters and prevent the continuation and worsening of losses [31,36,37].

Much of the early work centers around low-preparedness and prevention mechanisms [31,39]. Early warning systems are extremely effective and can save dozens of lives [16,29,37]. Moreover, physical barriers, such as dams and levees, can reduce the destructive impacts of floods; however, a community’s overconfidence caused by these protective structures may pose a challenge [2,26]. On the other hand, much research has been done on the impacts of reconstruction on the natural environment, usually addressed as “sustainable environment” or “environment-friendly decision” [11,31]. Debris clear-
The real-time monitoring of environmental changes and recording incident management have been the most frequently discussed topics in recent years (Figure 11). Governments are mostly known as the main bodies taking charge of PNDR projects. Their role varies in different countries; however, the resources we studied suggest that “coordination”, “plans and codes”, “financial issues”, and “assistance”, as well as emergency management, the consideration of lessons learned, and stakeholder participation management have been the most frequently discussed topics in recent years (Figure 11).

As shown in Figure 10, “Recovery of the sustainable environment”, “Preparedness against natural disaster”, “Retrofitting vulnerable buildings before disaster”, and “Critical Infrastructures Protection (CIP)” appear frequently in the context analysis.

![Figure 10. Frequency of factors in the environment sub-system.](image)

3.2.4. Government Sub-System

Governments are mostly known as the main bodies taking charge of PNDR projects. Their role varies in different countries; however, the resources we studied suggest that “coordination”, “plans and codes”, “financial issues”, and “assistance”, as well as emergency management, the consideration of lessons learned, and stakeholder participation management have been the most frequently discussed topics in recent years (Figure 11).

![Figure 11. The commonly mentioned keywords in the government sub-system based on context analysis.](image)
Even though the importance of establishing pre-disaster plans based on the region’s historical record of natural disasters has been discussed by several studies [30,43,44], due to the dynamic nature of PNDR projects, the revision of pre-established plans is crucial [29,34,45]. Similarly, firsthand experience and the results of key studies reveal the necessity of updating regulations and standards [19,39,41]. The modification of building standards, especially building codes and land-use regulations, as well as establishing a simplified procedure for obtaining building permits and specific guidelines to determine either the reconstruction or repair of damaged buildings, are of paramount importance [2,19,46–48]. The use of contractor consultation in modifying building codes has also been suggested by Chang et al. [49].

Moreover, coordination and collaboration among the recovery assistants is also important. Some authors have succeeded in demonstrating that insufficient and ill-timed collaboration among the responsible organizations has harmful impacts on PNDR projects [2,5,14,22,50]. On the other hand, the financial assistance of affected people [9,17,51], provided by the government, should be prioritized based on the beneficiaries’ real needs [20], and refers to a variety of schemes, such as loans with a long-term payback option [25,52], subsidies [20], tax reductions, and disaster insurance [40]. However, the usage of these financial packages should be supervised to avoid wasting budgets and generating a culture of dependency on external assistance [19,51]. Figure 12 illustrates the most frequently mentioned influential factors in the government sub-system, and places these within three groups. “Up-to-date reconstruction standards and legislation”, “Coordination and collaboration among assistants”, and “Establishment of pre-disaster plans based on past experiences” are the three most prominent factors in the government sub-system.

![Figure 12. Frequency of factors in the government sub-system.](image)

### 3.2.5. Project Management Sub-System

Project management is the most expansive sub-system and consists of multidimensional factors. The project’s objectives, construction control, planning, and design have been addressed in this sub-system. As shown in the word cloud in Figure 13, “reconstruction”, “stakeholders’ needs”, “housing”, “materials”, “resources”, and “design” appeared broadly...
in the research literature. However, infrastructures, plans, contractors, technologies, skills, transportation, cost and location have also attracted attention. The study divides the project management sub-system into six groups: “Post-disaster evaluation”, “Planning”, “Design”, “Construction”, “Procurement”, and “Completion and delivery”.

The design of permanent houses requires significant effort on the designers’ side. The needs and culture of the residents who have been identified by the government (preferably before a disaster) must be addressed in housing design [14,18,49]. Furthermore, the designers need to spend sufficient time learning about the affected area’s culture and the people’s lifestyles [4,5,18]. Climate design is another vital area that may directly affect residents’ satisfaction with housing [52,53].

Additionally, insufficient resources and shortcomings in procurement management constitute some of the most prevalent bottlenecks in PNDR projects [18,54]. Many studies have shown that the consideration of alternative materials [53], the availability of local materials [28], and the available resource database [31] are three possible means of surmounting these issues. Low-skilled or unskilled workmanship is another demanding barrier limiting PNDR projects’ success [55,56]. Not only can training expand local laborers’ knowledge, but also, through improving their skills, the path to livelihood revival may be completed more rapidly [12,15].

Studies by Ge, Gu and Deng, and Rani et al. [10,50] concluded that an effective schedule management plan is another prerequisite to achieving a successful PNDR project. Delays, which may have several internal or external causes, alongside inflexible deadlines and time pressures, can be resolved with the consideration of contingent resources and time buffers [15,32,57]. Additionally, an effective information management system can collect, analyze, and share the data among different stakeholders based on their needs [4,46]. Establishing an information dissemination system and informing the stakeholders about the PNDR project will lead to faster and more effective recovery [19,23,45,58].

The other factor that has gained consensus in the literature is the need to establish an evaluation system to assess the project’s success [9,23,48,52]. As witnessed in reality, most of the PNDR projects are assessed based on physical results, such as the number of built structures and the project’s duration [9,51,54,56]. However, PNDR projects are complex systems that should be seen as a whole. Such a system consists of several subjects and groups, and resembles a tree with numerous branches. Furthermore, the PNDR projects’ assessment requires a multi-factor index system to cover all the influential factors [3,48,59]. It should be noted here that some aspects of PNDR projects have intangible outcomes, which cannot be easily measured and are often ignored [32]. Besides this, selecting a
suitable time to evaluate the project’s success is challenging due to the long-term nature of the intended objectives [12].

One more potential bottleneck in PNDR projects is site selection [9]. The selected site’s distance from the old site and the city’s facilities is a crucial factor determining residents’ satisfaction [14,25,28]. Furthermore, people’s connections with their origin and culture should be preserved [47,54]. On the other hand, the residents’ safety and secondary hazard prevention should be considered in site selection [15,31,50]. Figure 14 provides an overview of the frequency of factors in the project management sub-system.

### 3.3. Influential Factors Based on Factors Interrelationship Analysis

The last section extracted the most frequently mentioned issues from several resources, including papers, books, and dissertations. Those factors have been grouped into five sub-systems and a number of groups based on System Thinking theory. However, before conducting any survey or fieldwork, the redundancy among the factors should be examined. Not only do overlaps among the criteria cause massive amounts of data that require delicate analysis, but they may also cause evaluation error. Furthermore, the researchers classified the identified criteria within a PNDR project’s life cycle and examined the internal and external interrelationships twice. The classification was done within the five main stages of a PNDR project’s life cycle: “Pre-disaster stage”, “Post-disaster immediate response stage”, “Planning and design stage”, “Procurement, construction, and completion stage”, and “Continual development stage”. The factors have been categorized based on the logic of System Thinking, as stated in the previous section. Following this, the factors have been correctly positioned, individual graphs for each stage have been drawn, and the interrelationships between the criteria have been shown. This process has been done twice to ensure the accuracy of the interrelationships. The results illustrated in Table 1 compare the influential factors in two rounds of factor interrelationship analysis.
### Table 1. The influential factors in the first and second round of factor interrelationship analysis.

| Life-Cycle | System Thinking | The First Round of Factors Interrelationship Analysis | The Second Round of Factors Interrelationship Analysis |
|------------|-----------------|------------------------------------------------------|-----------------------------------------------------|
| Pre-disaster stage | Social | • basic population information record | • basic population information record |
| | Economy | • special fund and resources (SFR) for disaster | • special fund and resources (SFR) for disaster |
| | Environment | • climate monitoring | • climate monitoring |
| | | • hazard warning systems | • facilities information record |
| | | • facilities information record | • facility maintenance |
| | Government | • emergency management plan emergency response training | • emergency management plan emergency response training |
| Post-disaster immediate response stage | Social | • people basic needs | • people basic needs (food, sanitation, shelter) |
| | | • temporary school | • temporary school |
| | | • rescue and medical aid | • rescue and medical aid |
| | | • psychological support | • psychological support |
| | | • criminal behavior prevention | • criminal behavior prevention |
| | | • NGOs’ assistance | • social network |
| | | • community ties | • assistance from NGOs |
| | Economy | • quick allocation of SFR | • quick and fair allocation of SFR |
| | | • fair allocation of SFR | |
| | Environment | • debris cleaning | • debris cleaning |
| | | • continuous disaster handling | • continuous disaster handling |
| | | • potential pollution treatment | |
| | Government | • immediate leadership and coordination | • immediate leadership and coordination |
| | | • infrastructure restoration | • immediate infrastructure restoration |
| | | • other countries’ assistance | • assistance from other countries or areas |
| | | • other districts’ assistance | |
| Planning and design Stage | Project Management | • damage assessment | • damage assessment |
| | | • site investigation | • site investigation |
| | Social | • local culture consideration | • consideration of local culture |
| | | • local climate consideration | • consideration of local climate |
| | | • community needs consideration | • consideration of community needs |
| | Economy | • reconstruction budget | • budget for reconstruction |
| | | • economy recovery and development plan | |
| | Environment | • environment protection plan | • environment protection plan |
| | | • property right protection | • property right protection |
| | | • pre-established plans revision | • pre-established plans revision |
| | | • integrated recovery plan | • integrated recovery plan (simplification of reconstruction procedure) |
| | | • clear definition of responsibilities | |
| | Government | • designer professionalism | |
| | | • site selection | |
| | | • reasonable housing design | |
| | | • resilient infrastructure design | |
| | | • reinforcement of standards | |
| | Project Management | • professional designers | |
| | | • site selection | |
| | | • resilient infrastructure design | |
| | | • green building design | |
| Social | • use of local labor | • use of local labor |
| | • use of local materials | • use of local materials |
| | • use of local construction methods | • use of local construction methods |
| | Economy | • cost control | • cost control |
| Environment | • waste management | • waste management |
| | • use of recyclable materials | • use of recyclable materials |
| Procurement, construction, and completion stage | Government | • supervision on reconstruction | • supervision on reconstruction |
| | | • simplification of reconstruction procedure | |
| | Project Management | • rapid construction method | • rapid construction method |
| | | • availability of construction materials | • availability of construction materials |
| | | • contractor competence | • contractor competence |
| | | • skillful labors | • skillful labors |
| | | • logistic management | • logistic management |
| | | • safety control | • safety control, quality control |
| | | • quality control | |
| | | • schedule control | |
| | | • prefabricated construction | • on-time completion and delivery |
| Life-Cycle | System Thinking | The First Round of Factors Interrelationship Analysis | The Second Round of Factors Interrelationship Analysis |
|------------|----------------|---------------------------------------------------|-----------------------------------------------------|
| Continual development stage | Social | • improvement of public awareness about natural hazards | • improvement of public awareness about natural hazards, livelihood development |
| | Economy | • livelihood development | • livelihood development, local business recovery |
| | Environment | • land restoration | • sustainable environment |
| | Government | • updated regulations and standards based on lessons learnt | • updated regulations and standards based on lessons learnt |
| | Project Management | • information management system | • information management system, hazard warning and protection systems |
| | | • safety guard facility construction | • safety guard facility construction, house condition evaluation after PNDR, infrastructure condition evaluation after PNDR |
| | | • house condition evaluation after PNDR | • house condition evaluation after PNDR, infrastructure condition evaluation after PNDR |
| | | • on-time completion and delivery | • on-time completion and delivery, budget control performance |
| | | • budget control performance | • budget control performance |
| | | | |
| Total number of the factors | 69 | 59 |

Figure 15 illustrates the approach applied for the second round of factor interrelationship analysis, and the factors interrelationships within each stage. Eventually, 59 final factors were input to construct a graph and highlight the interrelationships (Figure 16). In the end, based on the comprehensive graph, the objectives of the PNDR projects were determined. The nodes that denote influential factors have been delineated as PNDR projects’ objectives. The objectives form three groups: short-term objectives, mid-term objectives, and long-term objectives. The following section presents more details of the objectives.
Figure 15. Classification of the influential factors based on project life cycle and System Thinking.
4. Discussion

This study’s strength is the utilization of System Thinking, which was applied in the first section and used to generate a systematic perspective addressing PNDR projects as a whole. Based on the coding of the factors and the use of NVivo2020, word clouds for the sub-systems have been created, and groups were constructed. After this, the identified influential factors were placed in their relevant groups, and their frequencies were analyzed. Subsequently, the identified influential factors were modified by use of the factor interrelationship method. Five stages were then derived based on the PNDR project’s life cycle, and the interrelationships among the identified effectual elements were assessed. Considering the factors interrelationship analysis as a refinement process, the effective elements’ validity and relevance were examined over two rounds, and finally, 59 influential factors were extracted. Although this process combined a raft of the factors, seven key effectual elements have been added or separated from the old ones “rescue and medical aid”, “debris cleaning”, “continues disaster handling, budget for reconstruction”, “environment protection plan”, “use of local construction methods”, and “waste management” were out of consideration before factors interrelationship analysis and were added later. A summary of the effectual factors and their modification is given in Table 2.
Table 2. Modification of the influential factors before and after factors interrelationship analysis.

| Code | Influential Factors after Factors Interrelationship Analysis | Influential Factors Based on Context Analysis (before Factors Interrelationship Analysis) |
|------|-------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Pre 1 | Basic population information record | Successful beneficiary identification |
| Pre 2 | Special fund and resources (SFR) for disaster | Sufficient funding availability  Financial incentives or disincentives (Tax, subsidy) |
| Pre 3 | Climate monitoring | Climate real-time monitoring |
| Pre 4 | Facilities information record | Pre-disaster evaluation of existing building |
| Pre 5 | Facilities maintenance | Critical Infrastructure Protection (CIP)  Retrofitting vulnerable buildings before disaster |
| Pre 6 | Emergency management plan | Establishment and rehearsal of emergency plans and mitigation activities  Emergency response training |
| Post 1 | People’s basic needs (food, sanitation, shelter...) | Prompt answer to people’s basic needs (food, medical treatment, shelter, . . . ) |
| Post 2 | Temporary school | Temporary schools for children |
| Post 3 | Rescue and medical aid | NO CONSIDERATION |
| Post 4 | Psychological support | Psychological support from government |
| Post 5 | Criminal behavior prevention | Criminal behavior prevention |
| Post 6 | Social network | Retention of residents’ social networks and their trust |
| Post 7 | Assistance from NGOs | Participation of NGOs |
| Post 8 | Quick and fair allocation of SFR | Rapid fund collection for reconstruction  Well-administered financial acquisition  Priority setting among fund-requiring activities |
| Post 9 | Debris cleaning | NO CONSIDERATION |
| Post 10 | Continuous disaster handling | NO CONSIDERATION |
| Post 11 | Immediate leadership and coordination | Coordination & collaboration among assistants  Coordination among contractors  Sufficient control on people participation  Transparency and accountability (clearly defined roles and responsibility) |
| Post 12 | Immediate infrastructure restoration | Revitalization of critical infrastructures |
| Post 13 | Assistance from other countries or areas | Assistance from other countries or international organizations  Assistance from other provinces, districts, or cities |
| Post 14 | Damage assessment | Damage assessment & technical survey |
| Post 15 | Site investigation | Site investigation |
| Pla&de 1 | Consideration of local culture | Cultural and climate design to meet real needs  Consideration of community culture and beliefs |
| Pla&de 2 | Consideration of community needs | Fair social well-being for vulnerable groups  Effective and holistic communication system  Significant level of community participation |
| Pla&de 3 | Budget for reconstruction | NO CONSIDERATION |
| Pla&de 4 | Environment protection plan | NO CONSIDERATION |
| Pla&de 5 | Property right protection | Private & none-private property right protection |
| Pla&de 6 | Pre-established plans revision | Revision of pre-established plans after disaster  Establishment of pre-disaster plans based on past experiences |
| Pla&de 7 | Integrated recovery plan (simplification of reconstruction procedure) | Improvement and simplification in government mechanism  Integrated institutional planning  Integrated & continuous recovery management  Well-defined & accepted scope of PDR project |
| Pla&de 8 | Designer professionalism | Application of competence and experienced managers |
| Pla&de 9 | Site selection | Site selection |
| Pla&de 10 | Reasonable housing design | Availability of infrastructures in housing areas  Integrated housing reconstruction |
| Pla&de 11 | Resilient infrastructure design | Resilient & sustainable reconstruction (less vulnerabilities) |
| Pla&de 12 | Enforcement of standards | Enforcement of standards |
| Pro&con 1 | Use of local labor | NO CONSIDERATION |
| Pro&con 2 | Use of local materials | Assessment of availability of local resource before disaster |
Table 2. Cont.

| Code | Influential Factors after Factors Interrelationship Analysis | Influential Factors Based on Context Analysis (before Factors Interrelationship Analysis) |
|------|-------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Pro&con 3 | Use of local construction methods | NO CONSIDERATION |
| Pro&con 4 | Cost control | Cost control |
| Pro&con 5 | Waste management | NO CONSIDERATION |
| Pro&con 6 | Use of recyclable materials | Appropriate materials considering features of project |
| Pro&con 7 | Supervision on reconstruction | Supervision on agencies during reconstruction |
| | | Direct supervision on overall project |
| | | Supervision on usage of financial assistance |
| Pro&con 8 | Rapid construction method | Appropriate construction technology considering features of project |
| | | Rapid reconstruction method |
| Pro&con 9 | Availability of construction materials | Fair resource distribution |
| | | Sufficient available procurement |
| Pro&con 10 | Contractor competence | Assessment of contractors’ competency |
| Pro&con 11 | Skillful labors | Skilled labor force |
| Pro&con 12 | Logistic management | Logistic management |
| Pro&con 13 | Safety control | On-site safety management |
| | | Safety of structures |
| Pro&con 14 | Quality control | Quality control |
| Pro&con 15 | On-time completion and delivery | Effective time management |
| | | Timely decision-making in accordance with project’s features |
| ConDev 1 | Livelihood development | Recovery of livelihood |
| ConDev 2 | Improvement of public awareness about natural hazards | Increasing public awareness for prevention of hazards |
| | | Knowledge-based system & training |
| ConDev 3 | Local business recovery | Economy development plan based on area’s distinctive features |
| ConDev 4 | Sustainable environment | Recovery of sustainable environment |
| ConDev 5 | Updated regulations and standards based on lessons learnt | Up-to-date reconstruction standards & legislations |
| | | Documentation & knowledge transferring system |
| ConDev 6 | Information management system | Information management system |
| ConDev 7 | Hazard warning and protection systems | Preparedness against natural disasters |
| ConDev 8 | House condition evaluation after PDR | Result-based and holistic project evaluation method |

After this, the accumulative frequency of the final effectual elements was calculated. As shown in Figure 17, “Consideration of community needs”, “Immediate leadership and coordination”, “Updated regulations and standards based on lessons learnt”, “Integrated recovery plan (simplification of recovery procedure)”, “Availability of construction materials”, “Immediate infrastructures restoration”, “Improvement of public awareness about natural hazards”, and “Special fund and resources for disasters” are the most highly ranked effective factors. The “planning and design stage”, which contained factors with the highest accumulative ranking, is the most crowded stage, while the “pre-disaster stage” exhibits the lowest accumulative frequency of influential factors.

One of the most significant outcomes of this study is its clarification of the PNDR projects’ objectives. Although recovery projects should primarily be managed to balance time, cost, and quality, the continuous life cycle of PNDR projects necessitates the revision of their goals. The results of the factor interrelationship analysis categorized the objectives. These objectives were then grouped into three different stages. These included “short-term objectives”, which focus on immediate responses after natural disasters. The activities addressing the community’s needs and the restoration of damaged facilities arise here. “Mid-term objectives”, which mainly focus on the concept of “Build Back Better”, have been divided into delivery, planning, and construction. “Long-term objectives”, representing development after recovery projects, assess the fully comprehensive improvement of the
community’s ability to cope with the next natural disaster. Public well-being, the well-being of structures, and procedure well-being are the categories in this group.

Figure 17. The accumulative frequency of the final influential factors.

Factor interrelationship analysis enables the researchers to classify the PNDR project’s objectives, and the influential parameters or subsets. Table 3 demonstrates these findings. The main goal of the PNDR project has been identified as the “comprehensive and long-lasting success of the recovery project”.

| Goal                              | Timeline-Based Purpose | First Level Objectives | PSFs Subsets/Influential Parameters |
|-----------------------------------|------------------------|------------------------|------------------------------------|
| Comprehensive and long-lasting success of PNDR projects |                      | Short-term objectives | Community needs                     |
|                                   |                        |                        | People basic needs (food, sanitation, shelter...) |
|                                   |                        |                        | • Emergency management plan         |
|                                   |                        |                        | • Quick & fast allocation for SFR   |
|                                   |                        |                        | • Temporary school                 |
|                                   |                        |                        | • NGOs assistance                  |
|                                   |                        |                        | • Other countries or areas assistance |
|                                   |                        | Mid-term objectives    | Rescue and medical aid             |
|                                   |                        |                        | • Social network                   |
|                                   |                        |                        | • Site investigation                |
|                                   |                        |                        | • Emergency management plan        |
|                                   |                        | Long-term objectives   | Procurement, construction and completion stage |
|                                   |                        |                        | Proc&con 8, 23                     |
|                                   |                        |                        | Proc&con 7, 17                     |
|                                   |                        |                        | Proc&con 6, 13                     |
|                                   |                        |                        | Proc&con 13, 13                    |
|                                   |                        |                        | Proc&con 15, 25                    |
|                                   |                        |                        | Proc&con 12, 14                    |
|                                   |                        |                        | Proc&con 16, 11                    |
|                                   |                        |                        | Proc&con 4, 10                     |
|                                   |                        |                        | Proc&con 14, 7                     |
|                                   |                        | Continual development stage | ConDev 5, 45                       |
|                                   |                        |                        | ConDev 2, 34                       |
|                                   |                        |                        | ConDev 1, 21                       |
|                                   |                        |                        | ConDev 4, 16                       |
|                                   |                        |                        | ConDev 7, 16                       |
|                                   |                        |                        | ConDev 6, 19                       |
|                                   |                        |                        | ConDev 8, 16                       |
|                                   |                        |                        | ConDev 3, 14                       |
|                                   |                        | Pre-disaster stage     | Pre 2, 32                          |
|                                   |                        |                        | Pre 1, 12                          |
|                                   |                        |                        | Pre 3, 10                          |
|                                   |                        |                        | Pre 4, 5                           |

Table 3. PNDR projects’ objectives tree.
| Goal | Timeline-Based Purpose | First Level Objectives | PSFs | Subsets/Influential Parameters |
|------|------------------------|------------------------|------|-------------------------------|
|      |                        | People basic needs (food, sanitation, shelter . . . ) | • Emergency management plan  
   |                          |                        | • Quick & fast allocation for SFR | |
|      |                        | Temporary school      | • NGOs assistance  
   |                          |                        | • Other countries or areas assistance | |
|      | Community needs        | Rescue and medical aid | • Social network  
   |                          |                        | • Site investigation  
   |                          |                        | • Emergency management plan | |
|      | Short-term objectives   | Psychological support  | • Social network  
   |                          |                        | • NGOs assistance | |
|      |                        | Criminal behavior     | • Psychological support  
   |                          |                        | • Leadership & coordination | |
|      |                        | prevention            |                                    | |
|      |                        | Quick and fair allocation of SFR | • Emergency management plan  
   |                        |                        | • Damage assessment  
   |                        |                        | • Leadership & coordination | |
|      | Facilities and environment | Debris cleaning      | • Site investigation  
   |                        |                        | • Environment protection plans | |
|      |                        | Continuous disaster handling | • Site investigation  
   |                        |                        | • Climate monitoring | |
|      |                        | Immediate infrastructure restoration | • Damage assessment  
   |                        |                        | • Resilient infrastructure design | |
|      | Mid-term objectives     | Property right protection | • Revision of pre-established plans  
   |                        |                        | • Updated regulations and standards based on lessons learnt | |
|      |                        | Site selection        | • Integrated reconstruction plan  
   |                        |                        | • Local climate consideration  
   |                        |                        | • Community needs consideration  
   |                        |                        | • Environment protection plan  
   |                        |                        | • Site investigation | |
|      |                        | Reasonable housing design | • Local climate consideration  
   |                        |                        | • Community needs consideration  
   |                        |                        | • Local culture consideration  
   |                        |                        | • Professional designers  
   |                        |                        | • Integrated reconstruction plan  
   |                        |                        | • Enforcement of standards | |
|      |                        | Resilient infrastructure design | • Integrated reconstruction plan  
   |                        |                        | • Professional designers  
   |                        |                        | • Local climate consideration  
   |                        |                        | • Enforcement of standards | |
|      | Construction            | Cost control          | • Use of local labors  
   |                        |                        | • Availability of construction materials  
   |                        |                        | • Application of local materials  
   |                        |                        | • Rapid construction method  
   |                        |                        | • Contractors’ competence  
   |                        |                        | • Use of recyclable materials | |
|      |                        | Waste management      | • Debris cleaning  
   |                        |                        | • Use of recyclable materials | |
|      |                        | Quality control       | • Use of local construction methods  
   |                        |                        | • Skillful labors  
   |                        |                        | • Contractors’ competence  
   |                        |                        | • Supervision on reconstruction | |
|      |                        | Safety control        | • Skillful labors  
   |                        |                        | • Contractors’ competence  
   |                        |                        | • Supervision on reconstruction | |
|      |                        | On-time completion and delivery | • Availability of construction materials  
   |                        |                        | • Use of local labors  
   |                        |                        | • Logistic management  
   |                        |                        | • Application of local materials  
   |                        |                        | • Use of local construction methods  
   |                        |                        | • Use of recyclable materials | |
Table 3. Cont.

| Goal                        | Timeline-Based Purpose          | First Level Objectives                  | PSFs                                      | Subsets/Influential Parameters                                      |
|-----------------------------|---------------------------------|----------------------------------------|-------------------------------------------|---------------------------------------------------------------------|
| Long-term objectives        |                                 | Improvement of public awareness about natural hazards | • Information management system |･ Use of local labors  |
|                             |                                 | Livelihood development                  | • Use of local labors                     |･ Information management system  |
|                             |                                 | Local business recovery                 | • Information management system          |･ Local business recovery  |
|                             |                                 | Sustainable environment                 | • Updated regulations and standards based on lessons learnt |･ Application of local materials  |
| Procedure well-being        |                                 | Facility maintenance                    | • Facilities information record           |･ Environment protection plan  |
|                             |                                 | House condition evaluation after PDR    | • Information management system           |･ SFR for disasters  |
|                             |                                 | Structures well-being                   | • Updated regulations and standards based on lessons learnt |･ Reasonable housing design  |
|                             |                                 | Infrastructure condition evaluation after PDR | • Reasonable housing design               |･ Cost control  |
|                             |                                 |                                       | • Quality control                         |･ Resilient infrastructures design  |
|                             |                                 |                                       | • Waste management                        |･ Safety control  |
|                             |                                 |                                       | • on-time completion and delivery         |･ Resilient infrastructures design  |
|                             |                                 |                                       | • Infrastructure condition evaluation after PDR |･ Cost control  |
|                             |                                 |                                       | • Waste management                        |･ Safety control  |
|                             |                                 |                                       | • on-time completion and delivery         |･ Resilient infrastructures design  |
|                             |                                 |                                       | • Procedure well-being                    |･ Hazard warning and protection systems  |
|                             |                                 |                                       | • Updated regulations and standards based on lessons learnt |･ Climate monitoring  |

5. Conclusions

This study aims to illustrate the most significant criteria affecting PNDR projects’ success. However, there is still no clear understanding of the definition of a successful post-natural disaster recovery project. Although some research has applied the traditional evaluation method, which mostly focuses on quantitative progress, a method for assessing the progress of qualitative objectives and finding a satisfactory solution is lacking. As a result, this study has also attempted to define the objectives of a successful PNDR project.

This work’s main findings are drawn together and presented in this section.

- Through the application of System Thinking, the number of influential factors was reduced to 73. These factors were extracted from the context analysis and were inputted in the next step, the factors interrelationship analysis.
- Considering the continuous life cycle of PNDR projects as well as System Thinking allowed the study to revise the influential factors. Finally, the establishment of 59 effectual factors, which were analyzed in the last round of the factors interrelationship analysis and were considered as the life cycle-based objectives of PNDR projects, formed the most significant result of this study. This classification leads to the identification of PSFs and differentiates the factors that are the subsets/influential parameters of those goals.
- According to the discussion section, the “planning and design stage” contains the highest frequency of previously determined factors. On the other hand, the “pre-disaster stage” attracted the lowest attention, meaning that this group’s factors might be less determinative of the success of the PNDR project. However, the role of pre-
disaster planning and preparedness activities is undeniable, as addressed by He and Zhuang [59]. Moreover, the “continual development stage” exhibited a low impact on the PNDR projects’ success; however, the post-disaster preparedness and development stages seem to be neglected, but they are discussed by Dunford and Li [60]. Furthermore, it is necessary to re-examine the PSFs based on real cases.

- Different governments may prefer the timeline-based categorization of the recovery projects’ objectives after natural disasters. Some states may pay more attention to the short-term goals, while others focus on the long-term ones. As a result, the effectiveness of the objectives’ categories on the success of the PNDR projects depends on the nature of the projects and the stakeholders’ attitude.

The following has been demonstrated in this study:

- After assessing a huge body of literature, as shown in sub-Section 3.1, numerous factors were identified to be influential in the successful recovery after natural disasters. However, there is no obvious explanation of these projects’ objectives. Furthermore, the described effectual parameters suffer from the lack of a logical framework. This study illustrates a potential objective tree, depicting the different possible goals of PNDR projects. Each phase of this time-based objective tree can be used separately, as milestones, to evaluate the project’s progress. Moreover, this study has altered the prevalent unilateral approach toward PNDR projects into a more holistic perspective. The applied systematic logic attempts to answer the heterogeneous needs of stakeholders. Finally, the proposed framework of PSFs and the main objectives of PNDR projects lead to new approaches to the successful management of PNDR projects, employing System Thinking and the continuous life cycle concept simultaneously.

- There are some ways in which the ideas presented herein could be further developed. The method could be further refined by considering the validation of PSFs so as to form an Evaluation Index System for PNDR projects, which constitutes part of a bigger study. The future research projects of these authors will seek to use this methodology to identify PNDR projects’ CSFs and their measurement criteria, which will be evaluated through case studies.

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