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A Study on the Progress Management Model for a Large-scale City Construction

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Department of Civil & Environmental Engineering
The Graduate School
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Abstract

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In numerous countries around the world, for purpose such as development and growth of national technological industry, reduction of urban density and population distribution, establishment of environmentally-friendly infrastructure, relocation of national administrative capital, as well as establishment of multi-purpose complex combining commercial, residential, and leisure spaces, large-scale cities have been recently constructed, or construction projects for such cities are in progress or in planning stages.

In case of Korea, the "S-City," a city conceived and planned based on the Korean government's concept of "Administrative City," is under construction in the central part of the country as a decentralizing policy of national government's functions away from massively over concentrated capital region. The

S-City project is comprised of the public sector section that is funded by the government's project cost, and the private sector section that is funded by private investment. Overall, the project is structured so that government investment paves the way for private investment to follow. The public sector section of the project, including the construction of city grounds, traffic infrastructure, public facilities, culture and welfare facilities, etc., is driven by a government agency for the S-City project and a project developer. The private sector section, including the construction of municipal utility facilities, educational facilities, commercial facilities, etc. is comprised of numerous private companies and investors.

In order to provide an accurate assessment of the overall progress of a large-scale city construction project such as the S-City project with multiple agencies, contractors, and other entities a reasonable progress measurement method for accessing all facilities, public and private is critical. Currently, the progress measurement payment method, based on the project cost, and the total cost payment method are used as general methodology for measuring progress of large-scale construction projects. However, applying these methods to the S-City project will only measure the progress of the public sector side of the project, and exclude municipal utility facilities, educational facilities, commercial facilities, etc. that falls under the private sector side of the project; thus, using legacy methods will not result in an accurate assessment of the construction progress of the entire city. Furthermore, the progress measurement payment method does not render the physical completion of facilities in realistic fashion, and any changes to the overall budget will affect the level of projected progress.

Therefore, in order to provide an accurate and effective assessment of the level of completion in a large-scale city construction project, this study weighs key facilities of the city based on expert recommendations, and establishes a model for calculation and assessment of the weighed progress level. Moreover, through case study of the S-City project and the application of informational systems to the project, this study aims to propose an effective operational plan for progress management of large-scale city construction projects.

For this purpose, the progress rate data of city components are tiered based on the level of management, and surveys and interviews with city construction and project management experts were conducted in order to weigh each key facility that comprise a large-scale city. The Analytical Hierarchy Process(AHP) method was used for the survey in order to process subjective assessments into a more impartial and systematic data. For contract page level-data, which serves as an input to the progress of the entire construction project, control points(based on Earned Value) were applied for each step to measure the objective rate of progress for each lines of effort.

In order to review the availability of the proposed progress management model, a simulation was conducted based on the progress of key facilities in the completed parts of the basic living area. Using the projected progress rate, the progress of key facilities in the parts of the basic living area that are still under construction were compared, enabling decision support for

prioritizing investment to different facilities.

Finally, an appropriate module for assessing progress rate of key facilities in the S-City was established, and the information system for large-scale city construction projects was created incorporating the module.

Applying the progress management model and the information system proposed in this paper to large-scale construction projects such as large-scale city construction projects will ensure more effective utilization of government funds, as well as increased convenience for the public. Also, the results of this study and its proposed model can be applied to foreign large-scale city construction projects, fostering exports in related industries and ultimately contributing to Korea's national competitiveness.

Keywords: Project Management, Progress Management, Large-scale City Construction, Weighing of Facilities, Control Points

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Chapter 1. Introduction

1.1 Research background and purpose

Numerous countries around the world, for purpose such as development and growth of national technological industry, long-term national development through fostering of non-energy sectors, establishment of the "Silicon Savannah," reduction of urban density and population distribution, establishment of environmentally-friendly infrastructure, as well as establishment of multi-purpose complex combining commercial, residential, and leisure spaces, are conducting massive city construction projects. Such projects can be categorized based on the driving entities for the project: private, public, and public-private. Most of such projects are complex endeavors with multiple participants.

In case of Korea, following a policy of decentralizing governmental functions away from the massively concentrated capital region, a herculean effort dubbed as "S-City" is under construction in the central part of the country. The Korean government, with the aim of avoiding urban sprawl previously seen in new towns, is developing the S-City with the focus of expanding infrastructure, fostering the development of facilities that support self-sufficiency, and providing convenience facilities for the residents. Multiple entities are currently participating in the effort in order to construct governmental buildings, roads, and utility facilities. The investment structure is a public-private model, with the public sector leading the investment followed by private investment. The S-City project is comprised of the public sector section and the private sector section. The public sector section of the project is funded by the government's S-City project cost, and includes the construction of city grounds, traffic infrastructure, public facilities, culture and welfare facilities, etc. The private sector section is funded by private investment, and includes the construction of municipal utility facilities, educational facilities, commercial facilities, etc.

In order to provide an accurate assessment of the overall progress of a large-scale city construction project with multiple agencies, contractors, and other entities, such as the S-City project, a reasonable progress measurement method for accessing the progress of all key facilities is critical. Currently, the progress measurement payment method, based on the project cost, and the total cost payment method are used as general methodology for measuring progress of large-scale construction projects. The total cost payment method uses a total amount of executed cost to determine the project's execution rate. For this purpose, the budget includes various fees and costs including land compensation, design contract payments, site construction, construction costs, etc. While this method provides an appropriate measure of progress in smaller projects, the fact that it only considers executed budget leads to significant limitations in terms of its application towards large-scale city construction projects. In large-scale city construction projects, multiple entities other than the project operator participate in the project, and both private and public investments are involved. Thus, the total cost payment method is limited in its ability to realistically express project progress. Especially, large-scale city construction projects that last for a long time have a large variation between the level of costs incurred and actual realization of the project plan. In the total cost payment method, only the public sector investment is included in the executed budget and initial costs such as land compensation are also counted. Thus, the actual construction progress tends to appear to be far less than what the "executed budget" would suggest. This issue is also shared by the progress measurement payment method based on project cost. In most city construction projects, only the public section of the project, funded by government funds, are managed while forgoing the management of the private section, such as urban utility facilities, educational facilities, residential facilities, commercial facilities, etc. Therefore, legacy methods of progress management can only provide an understanding of the money spent on certain sections within a specific time period, and cannot be used as a systemic, step-by-step progress management tool for city construction management that provides milestones such as sections that needs funding, future funding timeline, land provision timeline, optimal lease timeline, etc. Since city construction is, by definition, a long-term endeavor, a reasonable prediction of the future using the analysis of current situation must be available and the results of such prediction must be used as a basis for policy decision-making. For this purpose, a practical progress rate that can accurately express the progress for each city construction stages is critical. A practical progress rate refers to a progress rate that can provide a realistic representation of actual level of city construction for each construction stages, in lieu of simple awareness of budget execution for the public section of the project.

To accurately access the progress of key components of a large-scale city construction project, the progress data for each key facility must be collected under reasonable and objective criteria, and the entire project must be organized under an activity-based tier system that reflects the characteristics of all participants. The scope of each activity must be specifically defined and divided under a completion standard by each stage. An objective progress assessment of the entire city must be generated based on the progress forecasting of activities and a systematic analysis and projection of remaining work must be followed.

Also, for successful completion of a large-scale city construction project, a massive amount of information generated during the course of the project must be effectively managed in order to support timely and accurate decision-making by the pertinent organization during the time of need. Project management of a large-scale city construction project is a complex matter, with massive costs and multiple participants. Thus, an effective management model for assessing the progress rate of key facilities, as well as an information system that utilizes such model's output are needed.

Therefore, this study provides a methodology for objectively determining the progress rate of the overall project, as well as a standard progress rate for each key facility within the basic living area through simulation and application of the actual progress rate. Also, this study is aimed at proposing a more appropriate model for large-scale city construction projects through tiring of city construction progress rate into different levels. It is expected that ordering organizations will be able to utilize this model to effectively manage the progress of city construction for large-scale city construction projects driven by central government organizations, local municipalities, or private investors.

1.2 Research scope and methodology

Large-scale city construction projects in Korea include industrial complex cities, bed towns such as Bundang and Ilsan, innovation cities for the purpose of decentralization of capital region and region-specific development, new towns developed under joint efforts of more than two municipalities, and partial administrative cities.[1)]

Internationally, large-scale city construction projects are underway with various goals such as establishment of environmentally-friendly infrastructure, development and growth of national technological industries, long-term economic growth through cultivation of non-energy industries, establishment of overall infrastructure for world-class competitiveness, as well as integration of residential, commercial, and leisure areas.[2)]

This study limits its scope to progress management of central government-driven large-scale city construction projects for relocation of central government administrative functions with the purpose of fostering balanced national development.

A collection of basic information such as the Work Breakdown Structure(WBS) and Sectional Breakdown Structure(SBS) was established to provide a building block for the progress management model for large-scale city construction projects. Also, a series of activity numbers were created to accurately represent unique characteristics of different key facilities that comprise the large-scale city. The activity number integrates project entities, construction project stages, as well as the WBS and SBS. Furthermore, the

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1) Jang, Sung Soo, Experience and Issues from New Town construction in Korea, Construction Culture Monthly, No. 214, p.164, Construction Culture Monthly, 2001.
2) The Cityquest KAEC Forum 2015.

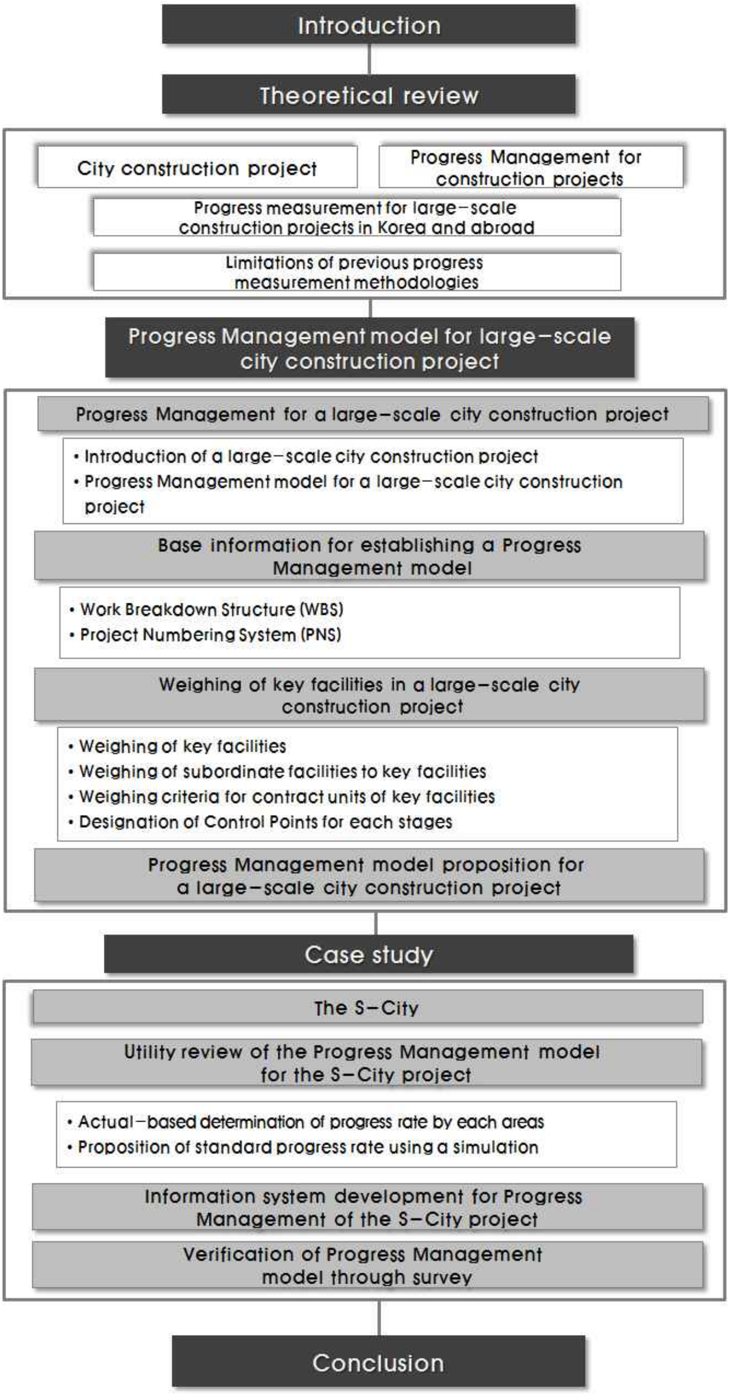
progress rate information of the city construction was tiered based on the level of management, and the concept of Earned Value(EV) was applied to activities(design, purchasing, and construction) in order to designate control points for determining objective progress rate of each activity. For information at the activity level, information provided by design firms and contractors were reviewed and adjusted to serve as input data.

The purpose of progress management is to ascertain the consistency of the project's actual progress with its schedule, as well as to prevent and mitigate risks such as project extension and cost increase. For this purpose, from the project's start to finish, planned schedule and actual timeline must be compared, and in case of any delays, mitigation plans must be made and step-by-step measures must be planned and executed in order to ensure more smooth execution of the project. Legacy methods only measure the progress in terms of cost and budget, and are limited in its accuracy in expressing the status of the construction project, due to the fact that cost allocation in construction projects tends to concentrate significant part of its cost in the beginning. Thus, it is difficult to use the data from such methods to formulate and apply project plan. Under legacy methods, duration and weight of each activities are not considered at all, and it is impossible to understand the connection and relationship between different endeavors. While the project operator may be able to obtain an understanding of how much money is spent, such understanding is limited in its usefulness towards determining a meaningful direction for the project. For city construction projects, a set of standards for effectively managing and controlling multiple participants is critical. Therefore, it is important to weigh each activities by importance, timeline, and potential effect on follow-up stages, instead of simply using the amount of money spent to perform progress management.

Weighing of key efforts(compared to the overall project) by each project entity was conducted taking into consideration a survey of city construction and construction project management experts on prioritization of key facilities in a large-scale city by importance. The Analytical Hierarchy Process(AHP) method was used for the survey in order to process subjective assessments into a more impartial and systematic data. In order to verify the results of this study, a series of interviews was conducted in order to verify the applicability of the model and originality of the progress management module.

Also, a series of simulations was conducted using the performance data of key facilities in completed basic living areas, as well as case study of progress management of a large-scale city construction project, in order to propose a standardized progress rate for each key facility based on the progress rate of basic living areas.

Figure 1-1 is a flow chart of this study. Theoretical analysis of progress management of city construction and other construction projects, determination of progress rate for large-scale national construction projects within Korea, as well as for large-scale city construction projects abroad, is conducted. WBS, SBS, and Activity Numbering Structure(ANS) are developed as part of the collection of basic information for the progress management of large-scale city construction projects. The importance of key facilities that comprise a large-scale city are weighed, guided by expert survey, and control points are defined for each facility in a way that reflects each facility's characteristics. A case study of the S-City is conducted based on the above, and a progress management information system is developed for the S-City project. Through interviews with city construction and project management experts, certain aspects of the project such as feasibility, availability, originality, and applicability are verified based on a set of pre-defined indicators. Finally, a proposal is made for follow-up research that enhances the real-world applicability of the model proposed in this study, resulting in increased efficiency and productivity of such application.



<그림 1-1> Research flow chart

Chapter 2. Theoretical review

In this chapter, definitions and scope of terms in the context of PMBOK, a global standard for project management in PMI, are reviewed. Also, city construction cases are reviewed, followed by a literature review of studies related to progress management of city construction projects in Korea and abroad, as well as those related to progress management of large-scale construction projects, with the aim of discovering methodologies applicable to large-scale city construction projects.

2.1 Scope of terms and relations in Project Management

2.1.1 Project/Program/Portfolio Management

(1) Project Management

Project management is the application of knowledge, skills, tools, and techniques to project activities to meet the project requirements. Project management is accomplished through the appropriate application and integration of the logically grouped project management processes, which are categorized into five process groups. These five process groups are initiating and planning, executing, monitoring & controlling, closing.

Managing a project typically includes, but not limited to:

- Identifying requirements;
- Addressing the various needs, concerns, and expectations of the stake holders in planning and executing the project;
- Setting up, maintaining, and carrying out communications among

stake holders that are active, effective, and collaborative in nature;

- Managing stake holders towards meeting project requirements and creating project deliverables;
- Balancing the competing project constraints, which include, but are not limited to scope, quality, schedule, budget, resource and risks.

The specific project characteristics and circumstance can influence the constraints on which the project management team needs to focus.

(2) **Program Management**

A program is defined as a group of related projects, sub-programs, and program activities managed in a coordinated way to obtain benefits not available from managing them individually. Programs may include elements of related work outside the scope of the discrete projects in the program. A project may or may not be part of a program but a program will always have projects. Program management is the application of knowledge, skills, tools, and techniques to a program in order to meet the program requirements and to obtain benefits and control not available by managing projects individually.

Program management focuses on the project interdependences and helps to determine the optimal approach for managing them. Actions related to these interdependences may include:

- Resolving resource constraints and/or conflicts that affect multiple projects within the program
- Aligning organizational/strategic direction that affects project and program goals and objectives, and
- Resolving issues and change management within a shared governance structure.

(3) Portfolio Management

A portfolio refers to projects, programs, sub-portfolios, and operations managed as a group to achieve strategic objectives. The projects or programs of the portfolio may not necessarily be interdependent or directly related.

(4) The Relationship Among Portfolios, Programs, and Projects

The relationship among portfolios, programs, and projects is such that a portfolio refers to a collection of projects, programs, sub-portfolios, and operations managed as a group to achieve strategic objectives. Programs are grouped within a portfolio and are comprised of sub-programs, projects, or other work that are managed in a coordinated fashion in support of the portfolio. Individual projects that are either within or outside of a program are still considered part of a portion. Although the projects or programs within the portfolio may not necessary be interdependent or directly related, they are linked to the organization's strategic plan by means of the organization's portion.

In city construction projects, various entities conduct tasks such as project management, program management, and portfolio management. The participant in charge of constructing facilities perform project management, whereas management entities for region or facilities perform program management, and the overall ordering entity in charge of the entire city construction effort conduct portfolio management. Facilities in a city are constructed through organic relationships and cooperation among these entities.

2.1.2 City construction project cases

A city is a home to many people, and maintaining a city requires various facilities and infrastructure such as roads, parks, water supply and drainage, schools, and department stores. Generally, most cities are developed organically. Sometimes, new cities are deliberately planned for reasons based on factors such as politics, economy, industry, and housing policy.

The concept of large-scale city construction must be objectively defined first as it is necessary for determining the target size, population, and project duration that is conducive to effective progress management of city construction projects. In this chapter, such definition is provided based on a case study of domestic and foreign city construction projects.

Lee, Yoi Hee (2008)[3] , following the emergence of serious issues such as overzealous real estate investment boom after the 1988 Olympics and subsequent explosion of housing prices, in regards to the first new towns(Bundang, Ilsan, Pyoungchon, etc.), reviewed all land areas located on the outskirts of Seoul that are available for massive development projects, and selected land areas exceeding approximately 9,900,000㎡ that are located within 20km of Seoul's city center as the subject of his research.

As shown on Table 2-1, the average area of first new towns is 10㎢, with average planned households and population of 59,000 households and 230,000 persons respectively, and project duration of 7 years.

3) Lee, Yoi Hee, Won, Bo Ram, Lee, Ji Un, A Study on the Comparison between the Plan and Development of A New Town, Gyeonggi Research Institute, p.13, 2008.

<Table 2-1> Overview of first new towns around capital region

Type	Bundang	Ilsan	Pyoungchon	Sanbon	Joongdong
Total area(㎢)	19.64	15.74	5.11	4.20	5.46
Population capacity (10,000 persons)	39	27.6	16.8	16.8	16.6
Housing construction (Cheonho)	97.6	69.0	42.0	42.0	41.4
Project period	'89.8～'97.12	'90.3～'96.12	'89.8～'96.12	'89.8～'96.1	'90.2～'97.1
Total project budget (100 billion KRW)	41.6	26.6	11.8	6.3	18.4
Project developer	Korea Land Corporation	Korea Land Corporation	Korea Land Corporation	Korea Housing Corporation	Korea Housing Corporation, Korea Land Corporation

Reference: Housing Manual (2003), Ministry of Land, Infrastructure and Transport, p.203, 2003.

Ahn, Gun Heok (2000)[4] stated that the criticism of first 5 new towns charging that the construction of the new towns accelerated the increase of population density of capital region and impeded the progress in balanced development of the entire nation has been the driving factor in the development of second new towns, which are more focused in promoting self-sufficiency and better housing environment.

As shown on Table 2-2, the average area of the second batch of new towns is 10.1㎢, with average planned households and population of 37,000 households and 110,000 persons respectively, and project duration of 8 years.

4) Ahn, Gun Heok, New Towns around capital region: Are they needed?, Korea Planning Association Discussion Panel, p.22, 2000.

<Table 2-2> Overview of second new towns around capital region

Type	Pangyo	Dongtan	Kimpo	Paju-Unjeong	Soowon-Gwangyo
Total area(㎢)	9.3	9.3	11.85	9.4	11.1
Population capacity (10,000 persons)	80.4	121	154	125	60
Housing construction (Cheonho)	26.8	40	53	46.3	20
Project duration	'03～'11	'01～'08	'07～'13	'03～'12	'05～'12
Project drivers	Gyeonggi-do, Songnam City, Korea Housing Corporation, Korea Land Corporation	Korea Land Corporation	Korea Land Corporation	Pajoo City, Korea Housing Coporation	Gyeonggi-do, Soowon City
Project budget (100 million KRW)	79,688	28,602	92,000	76,613	58,000

Reference: Kim, Hyun Soo, A Study on the Evaluation of the Second Batch of New Town, Vol. 19, No. 4, p.258, 2007.

Some cities are planned and constructed for the purpose of promoting balanced national growth. Following the increased awareness on the necessity of promoting balanced national growth after further acceleration of overpopulation of capital region, innovation cities are planned and constructed in Busan, Daegu, Jinju, etc. in order to ensure competitiveness through relocation of government agencies to other regions.

As shown on Table 2-3, the average area of the innovation cities is 4.5㎢, with average planned population of 27,000 persons, and project duration of 9 years.

<Table 2-3> Overview of innovation cities

Region	Location	Total area (1,000 m^2)	Population (1,000 persons)	Budget (100 million KRW)	Relocated agencies	Project duration
Busan	Yongdo-gu, Nam-gu, etc.	935	7	4,136	13	'06～'16
Daegu	Dong-gu	4,216	22	14,369	11	'07～'15
Gwangju, South Jeolla	Naju City	7,334	50	13,222	16	'07～'14
Ulsan	Joong-gu	2,984	20	10,438	9	'07～'16
Gangwon	Wonju City	3,596	31	8,843	12	'07～'14
North Chungcheong	Jinchon-gun, Umsong-gun	6,899	42	9,890	11	'06～'15
North Jeolla	Jenju City, Wanju City	9,852	29	15,297	12	'07～'16
North Gyeongsang	Kimchon City	3,812	27	8,774	12	'07～'15
South Gyeongsang	Jinju City	4,078	38	9,711	11	'07～'15
Jeju	Seogwipo City	1,135	5	2,921	8	'07～'15

Reference: Cho, Jin Woo, Problems and Improvements of Innovative Urban Development Project, Land and Construction Law Research No. 73, p172, 2006.

Joo, Kang Myong(2011)[5] referred to the efforts to develop special economic zones for the purpose of providing an optimal environment for increasingly-critical economic and business activities of business entities as "Economic Free Zones"

As shown on Table 2-4, the average area of the Incheon Free Economic Zone is 44.3㎢, with planned households and population of 68,000 households and 180,000 persons respectively, and project duration of 17 years.

5) Joo, Kang Myong, Current Status of Economic Free Zone and Its Tasks for Future, Journal of Management & Economics, Vol. 34, No. 1, p.83, 2011.

<Table 2-4> Overview of Free Economic Zones

Type	Songdo International City	Yeongjong Area	Chongra International City
Location	Yonsu-gu, Songdo-dong	Joong-gu, Yeongjong-do	Seo-gu, Geongseo-dong
Total area	53.45km^2	61.7km^2	17.8km^2
Budget	21 trillion and 450 billion KRW	19 trillion and 496.9 billion KRW	6 trillion and 352.8 billion KRW
Project period	2003 - 2020	2003 - 2020	2003 - 2020
Planned population	264,000 (103,000 households)	177,000 (67,000 households)	90,000 (33,000 households)

Reference: Incheon Free Economic Zone Authority (www.ifez.go.kr)

New towns overseas are diverse in their purpose as well, including decentralization of population density and mitigation of uneven development between new and old town areas.

As shown on Table 2-5, average area of overseas capital construction projects is 789.8㎢, with average population of 750,000 and project duration of 25 years.

<Table 2-5> Overseas capital construction projects

Type	Malaysia	Brazil	Pakistan	Australia
Purpose and characteristics	Population dispersion; relocation of administrative area, etc.	Vitalization of inland regions; defense from foreign invasion;	Decentralization of national capital; national security;	Establishment of independent federal state.
Location	Putrajaya	Brasilia	Islamabad	Canberra
Total area	50㎢	473㎢	906㎢	2,352㎢
Population	Apx. 330,000	Apx. 200,000	Apx. 900,000	Apx. 360,000
Project period	1995-2010	1955-1970	1960-1967	1908-1980

Reference: Ju, Sung Jae, Journal of the KRSA, Vol.19, no.2, pp.187～208, 2003

In France, the rapid population growth in Paris and its surrounding areas following the end of World War II has led to the development of the metropolitan city planning concept. Thus, the French government, for the purpose of mitigating overpopulation of Paris, has planned and executed plans for 5 new towns, as well as city reorganization plans.

As shown on Table 2-6, the average area of French new towns is 90.4㎢, with average population of 360,000.

<Table 2-6> French new towns

Area	Cergy Pontoise	Évry	Marne Lavalee	Melun Se'nart	Saint-Quentin-en-Yvelines
Total area(㎢)	80	41	150	118	63
Planned population	300,000	500,000	400,000	300,000	320,000
Population as of 1987	14,000	65,000	193,800	72,000	117,600
Residents	40,275	21,870	36,683	13,811	38,500

Reference: Jeong, In ha, A Study on French New Town Development and its Urban Historical Context and Space Utilization, The Architectural Institute of Korea, Vol.10, No.7, p.66, 1994.

According to Kim, Joong Un(2013)[6], both Korea and Japan had undertaken new town development projects in order to supply large-scale housing complex in the areas surrounding major cities plagued with overpopulation caused by the rapid economic development.

As shown on Table 2-7, average area of Japanese new towns is 789.8㎢, with average population of 160,000 and project duration of 27 years.

6) Kim, Joong Un, Prospect of population aging and urban management plan of new city in the 1st capital region by comparing with new suburbs in Japan, KRIHS, Policy brief, No.440, p.1, 2013.

<Table 2-7> Japanese new towns

Type	Chiba	Tohoku	Tama	Tsukuba
Distance from Tokyo	25～45km	25km	30km	60km
Planned area(㎢)	19.3	13.4	28.8	27.0
Planned population(person)	143,300	220,750	342,200	100,000
Current population(person)	81,230	127,740	210,090	76,250
Project period(year)	1969～2014	1974～1996	1966～2005	1968～1998

Reference: Lim, Chul Woo, Kim, Chang Ki, A Study on the Sustainability of new towns in Tokyo, Korean Institute of Science and Technology Information, Vol. 2, No. 1, p.22, 2001.

The review of both domestic and overseas new town development projects revealed various motivations and purposes, ranging from prevention of real-estate speculation, decentralization of the capital area, to balanced national growth.

Average total area of Korean new towns were 17.2㎢, with that of the Innovation City being the smallest at 4.5㎢, and that of the Free Economic Zone being the largest at 44.3㎢. Average planned population was 135,000, with that of the Innovation City being the smallest at 27,000, and that of the Free Economic Zone being the largest at 180,000. The average project period was 10.3 years, with first new towns around capital region with 7 years being the shortest and the Free Economic Zone with 17 years being the longest.

Average total area of foreign new towns were 299.3㎢, with the average population of 420,000 and average project duration of 26 years. The average numbers are decreased significantly after excluding special cases such as capital relocation, with the average total area of 54.1㎢, population of 260,000, and project duration of 25 years. Difference in climate, population, land area, and housing patterns (multi/single family) are the likely reasons for the rather significant difference between domestic and foreign new towns.

The purpose of this study is to provide a more logical and efficient methodology for project management of large-scale city construction projects. For this purpose, a "large-scale city construction project" is defined as a "city construction project that exceeds total area of 17.2㎢ and planned population of 130,000." This definition is accessed to be consistent with the standards provided by the Korean government.[7]

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7) The Korean government uses the term "New Town" to refer to large-scale residential developments. A "Large-scale New Town" is defined as a policy-driven development project with a total area exceeding 3,330,000㎡, planned and conducted for the purpose of providing self-sufficiency, comfort, convenience, and safety.(Ministry of Land, Infrastructure and Transport, 2005)

2.1.3 City construction research trends

Um, Moon Sup(2008)[8] reviewed various cases of city development projects aimed at creating a city free from many hazards and disasters, and proposed an environmentally-friendly disaster prevention measures for construction of new towns. In this model, Um focused on the threat of flooding, as it is the most common type of disaster in Korea. His first proposal was the construction of runoff reduction facilities, and his second was centered around disaster prevention methods at the urban planning level.

Kim, Jong Ryung(2009)[9], centering his work on the case of Jeonbuk innovation city, analyzed the indicators for the assessment of the impact of government agency relocation on regional economies. Also, he proposed measures for the cultivation of innovative environments and establishment of necessary functions, establishment of the business support service, establishment of industry-university-institute collaboration, as well as marketing. Based on these measures, he reviewed elements that are necessary to ensure that municipalities and project developers properly understand the concept of Innovation city and execute city development projects in an efficient manner under reasonable planning.

Ahn, Kwang Hyun(2009)[10] investigated urban landscaping issues

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8) Um, Moon Sup, A Study on the Urban Disaster Management of Newtown Construction, Kyeongwon University masters dissertation, 2008.

9) Kim, Jong Ryong, Long-term Impact Analysis of Innovation City Development on a Regional Economy - Focused on Gwangju-jeonnam Innovation City, Korea, Kyongwon University masters dissertation, 2009.

10) Ahn, Kwang Hyun, Urban Landscape Planning Officer applies case analysis on Sustainable landscape of New Town, Gyeonggi University masters dissertation, 2009.

of new towns in order to ascertain the fundamental cause of the issue and to propose solutions, as well as to provide future directions for new town development and landscaping improvement. He also reviewed natural scenery preservation strategies used in Tokyo, Japan, and Austin, US, etc.

Yoo, Chang Jun(2010)[11] compared research conducted by public research institutions and academic researchers in order to ascertain a set of standards for a city's self-sufficiency, in the context of balanced national development. Also, he considered the plausibility of connecting functions that support self-sufficiency in order to create a democratic urban space that distributes city functions evenly, and to ensure that a diverse cultural and welfare infrastructure is formed to achieve harmony between different social classes.

Park, Yong Gyu(2013)[12] reviewed the U-City projects currently being conducted by numerous municipalities, as well as similar projects overseas, and considered the implications of such projects. Also, he used the Songdo U-City project as an example to propose methods for project funding.

Park, Hyun Ook(2013)[13], using a sample of households within the administrative city, created and assessed a carbon monitoring model that can verify carbon emissions of each households. He identified several shortcomings and improved his model, ultimately proposing a carbon monitoring system model that can be applied to all new towns.

Kim, Am(2014)[14] analyzed the effect of the relocation of public

11) Yoo, Chang Jun, A Comparative Study on Enhancing Self-sufficiency Function in the Multifunctional Administrative City, Gongju University masters dissertation, 2010.

12) Park, Yong Gyu, A Study on Financing and Operation Subjects of Ubiquitous City Construction : Focused on Ubiquitous City-Songdo, Hansung University masters dissertation, 2013.

13) Park, Hyun Ook, Study on Carbon Emission Monitoring System for Eco-friendly Ubiquitous City Construction, Chungnam University masters dissertation, 2013.

agencies and private companies due to the construction of new towns, through his assessment of land price changes and inter-industry analysis.

Shin, Jae Ook(2014)[15] investigated issues with citizen participation model using the basic planning process for the Sejong metropolitan autonomous city, and proposed an alternative that ensures practical citizen participation through the adoption of a participation-centric paradigm.

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14) Kim, Am, A Study on the Land value Distribution Medium City Using GIS : a Case of Chung-ju City, Korea University Graduate School of Administration masters dissertation, 2014.

15) Shin, Jae Ook, On the Improvement of Participation System in New Town Planning Process : Focused on the Masterplan for construction about Sejeong Special Self-Governing City, Jeonnam University doctorate dissertation, 2014.

2.2 Progress Management for construction projects

This section provides a definition of progress management as a broader concept for managing progress of large-scale city construction projects, as well as an overview of pertinent research.

2.2.1 Definition of Progress Management

Progress Management, in the context of a construction project, refers to analysis of project progress as compared to the project plan through comparisons between planned and actual construction schedules, as well as establishment and execution of mitigation measures for any delays. The purpose of progress management is to prevent or mitigate any risks in order to ensure smooth execution of a project from start to finish, without cost overruns or schedule delays.

In progress management, the level of progress must be determined based on schedule, construction cost, work progress, and progress rate. They are defined as follows:

- Schedule: start and finish dates for each measured item
- Construction cost: construction cost for each measured item
- Weighed value: set based on construction cost, quantity of key items, etc.
- Work progress: set based on actual construction cost or material
- Progress rate: calculated by multiplying the work progress with appropriate weighed value

- Standard progress rate curve: a standardized curve used as reference for determining delays or expeditions compared to plan progress.

2.2.2 Previous progress measurement methodologies

Several progress measurement methodologies are currently in use. Some of the most common methods are: Estimated Percent Complete Method(EPCM), proposed by Thomas(1986)[16] ; Physical Progress Measurement Method(PPMM), an objective, measurement-based method; and Earned Value Method(EVM), commonly in use with contracts of US government as DOD(Department of Defense), DOE(Department of Energy).

(1) Estimated Percent Complete Method(EPCM)

In this method, the manager ascertains the progress of each activities and uses his/her subjective judgment to determine an estimated percentage of completion. This method uses simple criteria to determine the progress, thus reducing the difficulty of progress measurement. Hence, this method is advantageous for small, short-term(within 6 months) projects or projects with simple, repetitive activity. However, the relationship between percentage of completion and actual work quantity is uneven and inconsistent. Its reliance in subjective determination results in lack of objectivity and credibility, with the accuracy of the result greatly reliant on the individual's ability. Also, it is difficult to apply any design or work quantity changes with haste, and personnel reassignment may affect the measurement criteria.

16) H. Randolph Thomas. Jr, An Analysis of the Methods for Measuring Construction Productivity, CII Source Document No.13, The University of Texas at Austin, 1986.

(2) Physical Progress Measurement Method(PPMM)

This method measures progress as a ratio between total quantity and actual completion for each activity. It is applied to construction types where it is possible to measure the quantity of construction material used. Thus, this method is commonly used in construction projects in Korea. In order to use this method, construction work unit types must be clearly defined, a single, common unit of measurement must be designated, and the stock of construction material must be accurately taken. This method provides accuracy and objectivity, resulting in effective measurement of progress during project execution. However, establishment of measurement criteria and information collection require a large number of personnel. It is also difficult to collect sufficient information on work quantity and cost information in a timely manner.

(3) Earned Value Method(EVM)[17]

In this method, a constant set of Earned Values are assigned to each stage of each activity. It combines the simplicity of EPCM and objectivity of PPMM, and it is the mandatory method for major construction projects ordered by US Federal entities such as the Department of Energy, Department Of Defense, Department Of

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17) It is a systematic method used for integrated management of the budget, schedule, and performance for any tasks or projects. The various arms of the United States federal government, such as US Department of Defense(DOD), US Department of Energy(DOE), and the National Aeronautics and Space Agency(NASA), are current users of this method. As per "EVMS"(Earned Value Management System) of the American National Standard ANSI/EIA-748,the DOD, DOE, and NASA have drafted the Earned Value Management Guideline, Earned Value management System, and Earned Value Management Implementation Handbook respectively to codify the use of EVM. Thus, the use of the EVM is a mandatory requirement in any projects ordered by any departments or offices subordinate to these agencies. Also, in construction projects ordered overseas, it is common practice to include the EVM method in the contract by name. One of the most representative books that describes the EVM in detail is: Quentin W. Fleming and Joel M. Koffleman, Earned Value Management, PMI, 2010.10.

Transportation, National Aeronautics and Space Administration, etc. Also, in most of the plant construction projects overseas that are managed by Project Management Companies(PMC), this method is often mentioned in project contracts as a vital part of project management.

Since each contractor or owner may have different perspectives in regards to Earned Values, it is common to reach an understanding in this matter prior to project commencement or have it stipulated in the contract. However, this method carries a risk of overcomplicating the process.

2.2.3 Research trends on progress measurement methodologies for construction projects

In this section, both domestic and international research trends on progress measurement methodologies for construction projects are reviewed. Lee, Bok Nam(1997), Won, Dong Soo(2002), Lee, Sang Bum(2002), Choi, Yoon Gi(2003), are the representative examples in Korea, whereas overseas researchers such as Eldin(1989), Clark & Lorenzoni(1997) have studied the issue.

Lee, Bok Nam(1997)[18] proposed that based on the type of installation for each construction type, the progress rate must be measured as a ratio of planned/actual construction period. Actual quantity must be designated as the representative quantities. PPMM must be applied to representative construction types in which quantitative measuring is possible, whereas EVM must be applied to construction material with more than 1 month of installation time,

18) Lee, Bok Nam, Improvements to Construction Progress and Earned Value Measurement Methods, Construction & Economy Research Institute of Korea, 1997.

with the owner and the contractor being able to negotiate and adjust the details of the Earned Value. He proposed that a criteria for measuring progress must be developed as a national standard, objectivity in progress measurement criteria must be ensured, and criteria for determining the progress rate and the Earned Value must be consistent. Also, he recommended that: i) the owner and the contractor should be able to adjust the criteria for measuring standard progress rate through mutual agreement, based on the characteristics of the project ii) adjustments to the progress rate due to design or contractual changes must be done so with consideration to the unique characteristics of each site iii) in a single project, a single, consistent criteria for progress rate and Earned Value measurement must be applied for all contractors and construction projects in order to ensure consistency in the project.

Won, Dong Soo(2002)[19] conducted his research with the aim of determining the baseline for optimal performance measurement, as well as the overall progress rate, in the context of the EVMS. He pointed out difficulties in roadblocks and their mitigations common in construction projects, and proposed that the application of EVMS result in enhanced clarity and objectivity in performance measurement baseline and overall progress rate.

Lee, Sang Bum(2002)[20] stated that though EVMS is applied to some construction projects in Korea, it is difficult to control of schedule and cost integration because of cost breakdown structure.

19) Won, Dong Soo, New Methods of Establishing the Optimal Performance Measurement Baseline and Evaluation the Progress for Implementing EVMS, Seoul National University masters dissertation, 2002.

20) Lee, Sang Bum, A Study on the Optimal Duration Estimating Method by Line of Balance, Journal of the Architectural Institute of Korea, Vol. 17, No. 9, pp.233-240, 2002.

While some projects have achieved such management, the objectivity of the management criteria leaves a lot to be desired. He proposed an adjusted criteria for the integrated management by analyzing of the pros and cons of the Estimate At Completion(EAC) estimation.

Choi, Yoon Gi(2003)[21] developed a system for measuring construction progress through measurement of work-done performance and proposed a reasonable method to utilize the system. The method allows for the measurement of construction progress using earned value for high-level work fields, and work-done performance for divided activities. To measure the progress rate, the rate of work-done performance for each activity was weighed to take their importance into consideration. He stated that the objectivity of standard construction management information model and weighing criteria must be improved. In a study on material requirement planning by integrating schedule and cost(1999)[22] , he proposed a new type of categorization structure for the integration of different schedule and cost information. This structure provided and applied a progress measurement model for divided Activities to supplant legacy methods.

Eldin(1989)[23] applied a concept of dividing activities into weighed control points to measure earned value. His method for progress measurement was a comparatively objective one, where Earned Value is calculated as a ratio between budget and construction

21) Choi, Yoon Gi, Construction Progress Measurement System by tracking the Work-done Performance, Korean journal of construction engineering and management, Vol. 4 No. 3, pp.137-145, 2003.

22) Choi, Yoon Gi, A Study on Material Requirement Planning by Integrating Schedule and Cost, Seoul National University doctorate dissertation, 1999.

23) Eldin, N. N., “Measurement of Work Progress: Quantitative Technique”, Journal of Construction Engineering and Management, ASCE, Vol. 115, No. 3. pp. 462-474, 1989.

duration or quantity. He stated that while each project was weighed using the budget ratio to measure the progress rate of higher level efforts, there existed no mention the measurement of progress for specific construction types, relying on subjective judgment for progress measurement for activities. He stressed that since schedule, cost, and progress rate are interconnected and change over time, it is often difficult to track schedule and cost. To mitigate this difficulty, he proposed a standardized criteria for progress measurement and assessment during the early stages of the project that enables realistic progress measurement of construction projects. He introduced a method of using the WBS(Work Breakdown Structure) as a management tool to facilitate more accurate progress measurement. He proposed applying the earned value to progress management criteria to mitigate the difficulties encountered in using legacy methods.

Clark & Lorenzoni(1997)[24] proposed a weighed progress measurement method, where weighed value based on the budget ratio of activities are used as a basis for determining the progress rate on the upper level. This method required objectivity in progress measurement and was determined to be unclear in its criteria for weighing representative construction types.

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24) Clark F. D. & Lorenzoni, A. B., Applied Cost Engineering, Marcel Dekker, 1997.

2.3 Progress measurement for large-scale construction projects in Korea and abroad

2.3.1 Analysis of progress measurement methodologies for large-scale construction projects in Korea

Recently, multiple large-scale construction projects have been completed or in progress in Korea. The government has not provided a standardized method for measuring the progress of construction projects, and case-by-case approach is the norm. This section reviews the progress measurement methods used in several major construction projects in Korea.

(1) Korea Train Express construction project[25)]

At the early stages, the progress rate was measured only as a ratio of budget execution, resulting in changes when overall budget is changed. Also, the duration of Activities and their importance were not reflected, leaving the progress of each construction type unclear. As the project progressed, the contract amount was designated as the weighed value for the project cost and the percent complete method was applied. However, this method had the disadvantage of changing progress rate after each contract signing. Hence, the actual construction cost was chosen as the weighed value and the previous quantity was converted to amounts of money.

For land compensation, the allocated cost was chosen as the weighed value, whereas land progress rate was measured using the area of compensated land as the basis. Contract price was the

25) Korea Train Express, Project Management Procedure, S-26

weighed value for design and services. Overhead such as supervision and project management costs were excluded. For construction, the actual cost(excluding overhead) was chosen as the weighed value and the progress rate was measured as a ratio of planned and performed work. While commissioning is an importance part of the project, no weighed value was chosen.

(2) Seoul Subway construction project[26)]

Progress measurement was conducted by calculating a percentage of each activity's weighed value to the overall weighed value. The design was based on man hours and output, purchasing was based on the price of total purchases. For construction, actual construction cost and quantity were the bases of measuring, and commissioning was based on the number of personnel. In progress measurement of design, activity completion rate was assigned by the activity stage of the output submitted by the contractor. For purchasing, completion rate was assigned to each activity by each purchasing contract, based on purchase price. Weighed value of construction was determined based on the construction fields such as civil, architecture, rail, electricity, signal, etc. For commissioning, personnel were assigned to each activity as needed.

(3) Incheon International Airport construction project(Phase 1)[27)]

For Incheon international Airport construction project, the importance, difficulty, and duration of the design stage were determined to be more important than the project cost; thus, the weighed value was adjusted accordingly. Determined weighed value was applied in order to ensure that changes to the project cost will

26) City of Seoul Subway Construction Center, Construction Schedule Procedure, 1999.
27) Incheon International Airport Construction Corporation, Construction Schedule Procedure.

not affect the weighed value for each stage. Purchasing progress rate is less important as the activity proceeds rather smoothly after design completion. Thus, the weighed value of the construction stage, which includes purchasing, is decreased, and that of the design stage was increased. The construction and purchase order placement does not incur any cost. However, as order placement is critical for the entire project's schedule, and in order to foster timely order placement, the weighed value was increased. A method of determining detailed progress rate for the construction stage was finalized and applied to the preparation of(or changes to) the progress rate table by contractors. Supervisory and project management costs, which are overheads, were excluded from the progress measurement. For the commissioning stage, its importance was greater than its share of the project costs and its weighed value was increased.

(4) Nuclear Power Plant construction project

The nuclear power plant construction project is a long-term, continuous project. Weighed values for each category were determined based on each category's importance, rather than relying on the project costs. Weighed values for design, construction, and commissioning were increased. Measures were taken to ensure that such values are not changed following any changes to the project cost. Land compensation was excluded from progress measurement.

2.3.2 Analysis of progress measurement methodologies for large-scale city construction projects in Korea and abroad

As mentioned above, major cases of city construction projects in Korea include Bundang, Ilsan, Pyoungchon, Sanbon, and Joongdong. These projects were conducted with the aim of developing large-scale residential complexes for mitigating housing shortages within capital region, and thus categorically different from current complex large-scale city construction projects. While finding which progress measurement methods were used for these projects was difficult, a brief overview of such methods was made available by the use of information system[28)] currently in use by the Korea Land & Housing Corporation(LH).

28) LH Next-generation Information Systems Project Management System User Manual, 2016

<Table 2-8> City development progress designation criteria

Category	Subcategory	Unit	Notes
Construction service cost	Preparation(Construction service cost)	Area/cost	
Service cost	Construction(Design service cost)	Cost	
	Construction(Survey service cost)		
	Preparation(Design service cost)		
	Preparation(Survey service cost)		
Share in Expenses	Preparation(allotment for roads)		
	Preparation(allotment for groundwork)		
	Preparation(allotment for other facilities)		
	Preparation(allotment for waste disposal)		
	Preparation(Ecosystem conservation cooperation charge)		
	Preparation(allotment for school facilities)		
	Preparation(allotment for sewage facilities)		
Other preparation costs	Construction(other construction)		
	Preparation(other construction)		

The performance history by project sections was further divided by subcategories, and monthly, quarterly, and total costs were analyzed in the context of project costs in order to determine actual performance as compared to planned performance. Weighed values were not assigned to subcategories. It can be determined that previous city development efforts used largely same management methods.

Many nations around the world are conducting large-scale city construction or are in the process of planning such efforts. City construction projects, in terms of driving entities, can be categorized as public-led, private-led, or Public-Private-Partnership(PPP) projects. Public-led projects tend to focus on prioritizing the completion of public goals, whereas private-led projects tend to focus on profitability than public benefit. PPP projects are generally the mix of the two.

One notable example of these foreign developments is the King Abdullah Economic City in Saudi Arabia, which is being built by the Emarr Group, a firm that was in charge of constructing Dubai. The goal of the project is to reach the population of 2 million by 2025. Private firms in charge of city construction focus on profitability, directing their resources to residential and commercial buildings in order to create a revenue stream from rental fees. Thus, progress measurement by such firms tend not be based on physical completion of facilities, often using the sales and rental performance of lands and facilities as the metric.

Most of the private-led projects, such as the King Abdullah Economic City project, manage their progress rates based on sales and rental revenue. Data for public-led projects were mostly unavailable due to their secretive nature.

2.4 Limitations of previous progress measurement methodologies

Studies done in Korea generally stress the necessity of ensuring objectivity in choosing representative function for each activity, as well as in progress measurement. Such studies propose various modes of applying weighed values for the purpose of measuring overall progress for upper-level stages of each activity. Foreign studies also attempt to conduct a overall management of the schedule and cost, and they propose objective quantification of progress measurement metric, etc.

Some projects are managed by assigning weighed values that reflect their characteristics. While the EVM, a method used in US government contracts, was partially applied, it was stated that improvement of objectivity in progress measurement and weighed value assignment are needed.

However, research pertaining to progress measurement of city construction remained unpopular. Especially, no study measured overall progress while taking private sector activity into consideration. Thus, it can be said that this study is an original effort that integrates private sector activity into progress measurement. Also, in most large-scale construction projects in Korea, the progress measurement is done with project costs. This leads to unrealistic depiction of physical completion of facilities and the progress rate tend to change as project cost changes.

Therefore, this study aims to propose an objective model for measuring the overall progress of the entire city, based on previous literature and information pertaining to progress measurement of construction projects. To this end, it is also the goal of this study to develop an information system that integrates weighing structure for characteristics, participating entities, and key facilities of large-scale city construction projects.

Chapter 3. Progress Management model for a large–scale city construction project

3.1 Progress Management for a large–scale city construction project

3.1.1 Overview of a large–scale city construction project

Numerous large-scale city construction projects, such as S-City in Korea, Cyberjaya in Malaysia, Dubai and Saadiyat Island in UAE, and King Abdullah Economic City in Saudi Arabia have been completed or are in progress. Such projects involve massive investments and long construction schedule, along with multiple stakeholders and operators.

Various development methods are in display in these projects. Some projects have designated project developer to take charge of the entire region, while others have project developer assigned to functional areas.

Facilities that are commonly involved in these projects include, site preparation facilities, transportation facilities, urban utility facilities, public facilities, and residential facilities. Table 3-1 provides a detailed listing of these facilities.

<Table 3-1> Key components of large-scale city construction projects

Type	Key facilities	Notes
Site preparation	Groundwork, landscaping, etc.	
Transportation facilities	Metropolitan roads, urban roads, etc.	
Public facilities	City halls, education boards, research institutions, etc.	
Culture & welfare facilities	Welfare, sports facilities, etc.	
Urban utility facilities	Electricity, gas, heating, communications, etc.	
Educational facilities	Kindergartens, elementary/middle/high schools, universities, etc.	
Residential facilities	Multi/single-family housing, etc.	
Commercial and business facilities	Commercial facilities, neighborhood facilities, etc.	
Other facilities	Gas stations, parking spaces, funeral homes, hospitals, industrial facilities, etc.	

As shown on Table 3-1, site preparation facilities are comprised of groundwork, landscaping, etc., whereas transportation facilities are comprised of metropolitan roads, urban roads, etc., and public facilities are comprised of city halls, education boards, research institutions, etc. Culture & welfare facilities include culture facilities, welfare facilities, sports facilities, etc., and urban utility facilities include electrical facilities, gas facilities, heating facilities, communications facilities, waste management facilities, etc. Educational facilities include kindergartens, elementary/middle/high schools, universities, etc., commercial facilities include commercial facilities, neighborhood facilities, etc., and other facilities include gas stations, parking spaces, hospitals, etc.

In some projects, a certain section is designated as a specialized section for some of the key facilities, whereas other projects distribute such facilities more evenly. Regardless of distribution, all facilities must be systematically categorized and managed.

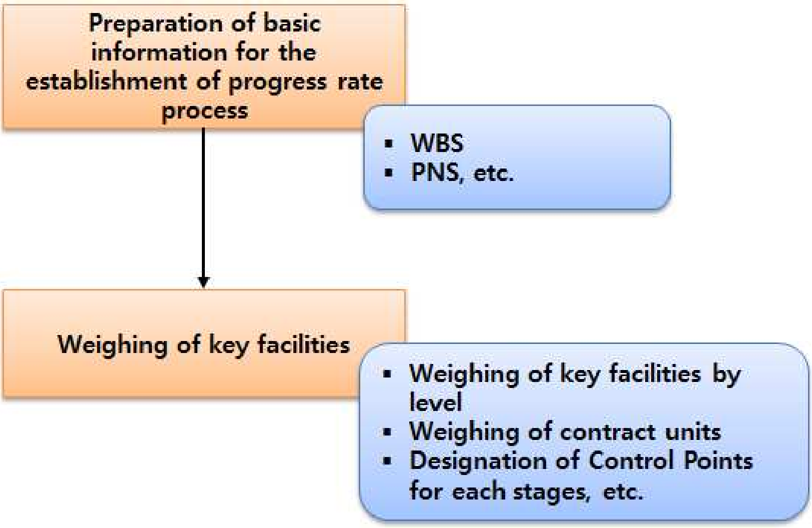
3.1.2 Progress Management method for a large-scale city construction project

The purpose of progress management is to prevent or mitigate any risks in order to ensure smooth execution of a project from start to finish, without cost overruns or schedule delays.

In large-scale city construction projects, a overall progress management in addition to progress management of individual efforts is critical. For this, it is necessary to collect systematic construction information in order to enable rapid and accurate assessment of construction progress.

A review of previous literature and cases reveal that research into progress management of city construction is lacking, and progress management practice tended to focus only on project costs, unable to realistically render the realities of city construction.

Therefore, a new modal that objectively and systematically shows the progress of large-scale city construction projects, including private facilities, must be proposed. To this end, it is necessary to establish a collection of basic information. Figure 3-1 shows the progress management procedure for large-scale city construction project.



<Figure 3-1> Procedures for Progress Management of large-scale city construction projects

In this study, Work Breakdown Structure(WBS) and Activity Numbering System(ANS) were applied to progress management, and weighed values were assigned by all levels and contract units, and control points were established within contract units.

3.2 Basic information for establishing a Progress Management model

To effectively manage progress of large-scale city construction projects, one must reflect the unique characteristics of each facility and ensure that performance data is aggregated and managed in a systematic manner. To that end, this study develops and applies an identification system that serves as basic information necessary for progress management of large-scale city construction projects.

The identification system fosters effective collection, analysis, and usage of common information through naming or numbering of Activities or efforts. It provides timely reports for commonly applied items, designates work boundaries, sets the budget, tracks costs, and serves as a basic infrastructure for digitization of efforts. Thus, the identification system establishes identification tags, numbering system, and usage guidance for efforts and records. Also, the system provides a consistent numbering and identification system, and its use of common categorization structure enables information sharing and more rapid and accurate information searching. The work breakdown structure and project numbering system are most common examples of identification system.

3.2.1 Work Breakdown Structure(WBS)

The WBS involves hierarchical categorization of detailed elements of a project in order to systematically categorize and define objectives, efforts, and outputs.

Through hierarchical representation of a relationship between final objective and its subordinate items, it identifies detailed activities and connects them to their superior efforts, and organizes them into a single group to provide a hierarchical structure for planning and management. The Project Management Institute in the United States, in its publication Project Management Body Of Knowledge(PMBOK), defines the WBS as the following:[29]

A deliverable-oriented grouping of project elements which organized and defines the total scope of the project. Each descending level represents an increasingly detailed definition of a project component. Project components may be products or services.

In the Earned Value Management System, used by US Department Of Defense(DOD), Department Of Energy(DOE), Department Of Transportation(DOT), and National Aeronautics and Space Administration(NASA), the WBS is defined as the following:

A product-oriented family tree division of hardware, software, facilities, and other items which organized, defines, and displays all of the work to be performed in accomplishing the project objectives.

(1) Key functions

Two of the most basic purpose of WBS is to i) ensure that all necessary tasks are included and ii) ensure that no unnecessary tasks are included.

In order to provide a basic framework for communication of scope/cost/schedule, assignment of responsibilities, monitoring, and management, the WBS divides the project into smaller, manageable activities and elements. Its key functions are as follows. Defines all

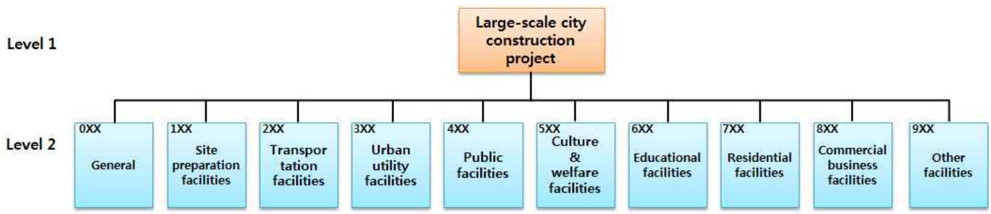
29) PMI, A Guide to the Project Management Body Of Knowledge(PMBOK®GUIDE) - Fifth Edition, 2013.

tasks that must be completed in order to achieve the project objective, prevents redundancy or omission of tasks, and serves as a communication tool between project participants. Provides basic framework for cost and schedule management and conducts systematic management of project plan/actual/changes.

(2) Considerations

Considerations when using the WBS are as follows. All tasks must be categorized and defined without omission at each level/tier in order to categorize them into a hierarchical structure that aids visualization of all tasks; all tasks must be categorized into manageable levels to ensure clear management; the criteria for task categorization must be set clearly, taking into consideration regional/physical/functional/logical/organizational categorization concepts; ensure synchronization and connection of and between categorization criterion; ensure clear and overall understanding for all participants; and create numerical and alphabetical codes for categorization criterion in order to maximize user availability.

Figure 3-2 represents the WBS as applied to large-scale city construction projects.



<Figure 3-2> Work Breakdown Structure of large-scale city construction projects(Level 1&2)

Level 1 is a sum of all facilities, and Level 2 represents common key facilities that comprise cities. Level 3 represents subordinate facilities to Level 2 facilities. For example, level 2, "1XX Site preparation facilities" is made up of groundwork, landscaping, and demolition at Level 3, and "3XX Transportation facilities" is made up of urban transit roads, outer ring roads, and municipal roads at Level 3.

It is necessary to ensure that construction information is systematically aggregated, reviewed, and analyzed through the establishment of PNS that includes activity numbers, etc.

3.2.2 Project Numbering System(PNS)

The Project Numbering System is a numbering system that assigns numbers to all elements of a project, such as tasks, outputs, and organization. It is aimed at supporting all participating persons to ensure that they can collect, exchange, analyze, and aggregate information in a convenient and consistent manner throughout the project. The system is based on the WBS. Generally, the system contains unique numbering systems for each task and subject. It is used to identify facilities, material, and activity.

In nuclear power plant construction project, PNS such as the document and drawing numbering system, Activity Numbering Structure(ANS), construction cost account numbering system, special numbering system, and project document categorizing system[30]. For the Incheon international airport project, the PNS is used for schedule unit number, cost control accounts, and equipment numbe r.[31]

Of all PNS categories, the ANS is a must in progress

30) Korea Electric Power Corporation, Nuclear Power Plant Project Numbering System Procedure Manual.

31) Incheon International Airport Corporation, Incheon International Airport Project Numbering System Procedure Manual.

management. The ANS is a numbering system that reflects management/facility/functional properties of each project, and it incorporates WBS as a family tree for schematization, organization, and definition of all project tasks. It also reflects regional properties if project area is large. This study proposes a basic concept for ANS that can be applied to large-scale city construction projects, as shown on Figure 3-3.

<Figure 3-3> Basic concept of the Activity Numbering Structure

In Figure 3-3, management properties represent project entities for city construction, and facility properties can be expressed with WBS. Regional properties may be applied if regional distinctions are necessary, and functional properties represent project stages such as design, construction, and procurement, etc.

3.3 Weighing of key facilities in a large-scale city construction project

3.3.1 Weighing of key facilities

Weighed values for key facilities that comprise the large-scale city construction project must be determined by their importance to the city, as opposed to simply relying on their share of the budget. The list of facilities should also include those from private sector efforts.

The weighed values for facilities can differ greatly due to each facility's properties. Thus, a survey of city construction and project management experts and action-level personnel was conducted to aid in its determination.

(1) Survey overview

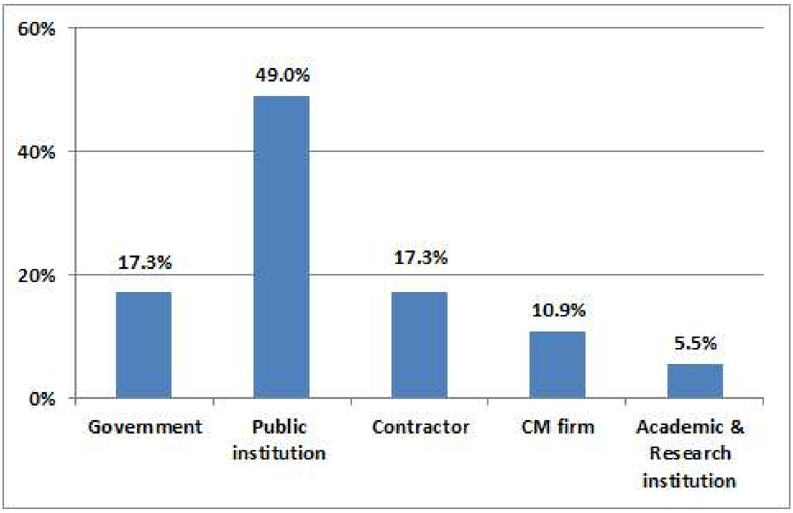
The Analytical Hierarchy Process(AHP) method was used for the survey in order to process subjective assessments into a more impartial and systematic data. As AHP is able to provide more meaningful results when two options are compared side-by-side, a binary comparison was conducted to determine the most optimal conclusion.

In this study, a series of surveys that integrate AHP method to determine that importance of 9 key facility types was conducted. Table 3-2 is an overview of the survey.

<Table 3-2> Survey overview

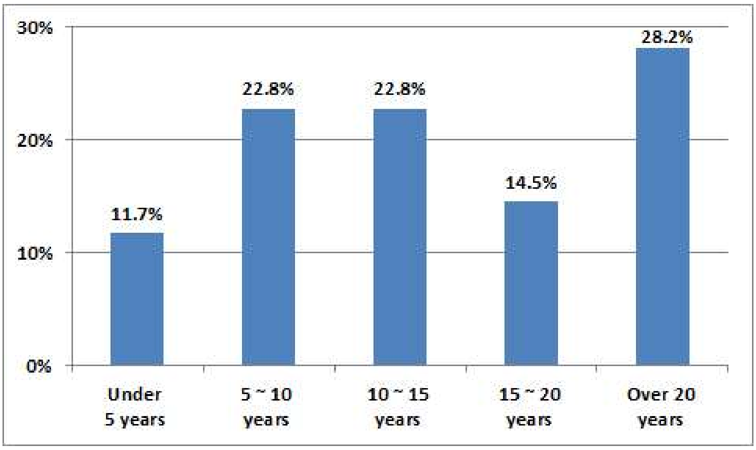
Type	Details
Purpose	Determine the importance of Level 1 facilities
Date	2014.12.01 ~ 2015.3.31
Subject	Experts and action-level personnel in government agencies, public institutions, academic and research institutions, contractors, etc.
Method	Physical interviews and E-mail surveys
Recovery rate	145 out of 170 recovered(85.3%)

The subjects are about 170 persons, including city construction and project management experts and action-level personnel in government agencies, research and academic institutions, and contractors. A total of 170 surveys were handed out and 145 of them were recovered(recovery rate: 85.3%). Figure 3-4 represents the breakdown of survey respondents by organization. On Figure 3-4 below, 49.0%(71) of the respondents were employed by public institutions, followed by public institutions(17.3%, 25), government agencies(17.3%, 25), CM firms(10.9%, 16), and academic and research institutions(5.5%, 8).



<Figure 3-4> Breakdown of survey respondents by organization

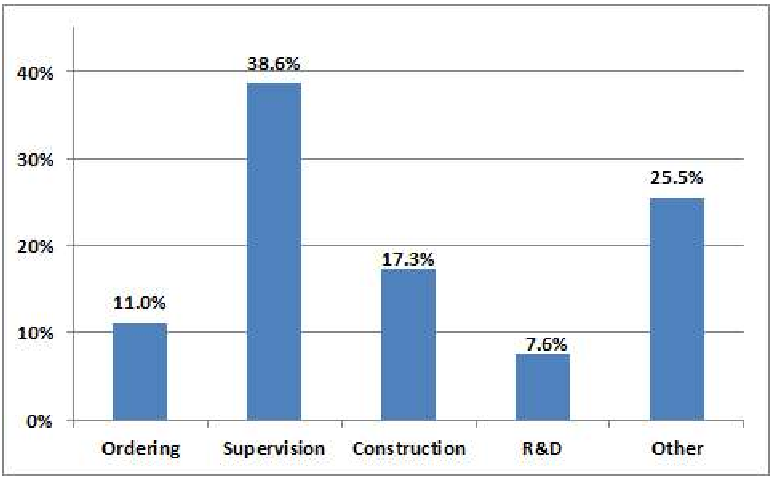
Figure 3-5 is a breakdown of survey respondents by experience in 5 year intervals.



<Figure 3-5> Breakdown of survey respondents by experience

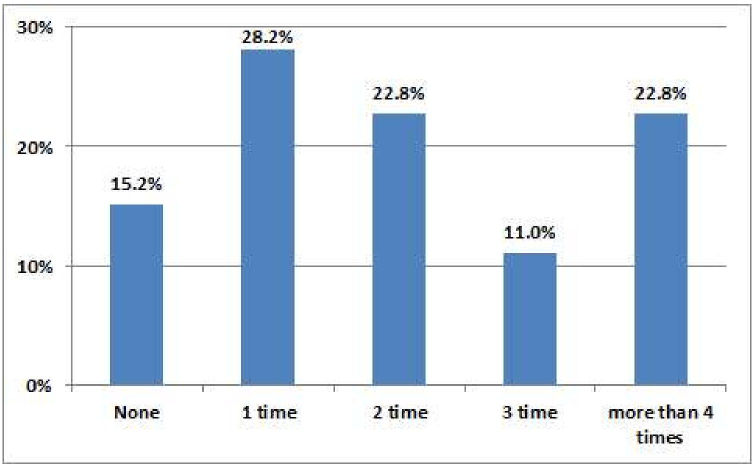
On Figure 3-5 below, 28.2%(41) of the respondents had an experience of 20 years and above, followed by 15 years and above(14.5%, 21), 10~15 years(22.8%, 33). About 65.5%(95) of the respondents had more than 10 years of experience.

Figure 3-6 below is a breakdown of survey respondents by role 38.6%(56) of the respondents had a supervisory role, followed by construction(17.3%, 25), order placement(11.0%, 16), R&D(7.6%, 11) and other(25.5%, 37). Most of the respondents were involved in urban planning for government agencies, construction planning or administration in public institutions, or project management in CM firms.



<Figure 3-6> Breakdown of survey respondents by role

Figure 3-7 is a breakdown of survey respondents by experience in large-scale city construction projects. Most of the respondents(84.8%, 123) were involved in a large-scale city construction project at least once. 56.6% of the respondents were involved more than 2 times, followed by 3 times(33.8%, 49), and more than 4 times(22.8%, 33).



<Figure 3-7> Breakdown of survey respondents by experience in large-scale city construction projects

In order to determine the weighed value for the importance of key facilities that comprises large-scale cities, respondents filled in survey sheets in a form of binary comparison that is designed to direct respondents to determine the comparative importance of assessment items. The maximum value was 7, and the results were averaged to determine the weighed values for the final checklist. Table 3-3 demonstrates the level of importance for each numbers under the 7-point metric.

<Table 3-3> Criteria for binary comparison

Importance	Definition	Description
1	Equal importance	Two items are of equal importance
3	Moderate importance	Based on experience and judgment, one item is preferred slightly over another
5	Strong importance	Based on experience and judgment, one item is preferred strongly over another
7	Very strong importance	Based on experience and judgment, one item is preferred very strongly over another
2,4,6	Average of the above	Based on experience and judgment, the comparative value between items is an average of the above.

The interview and survey sheets are attached as [Appendix 1].

(2) Comparative importance measurement through AHP

The 9 key facilities(Level 1) serve as assessment items for the AHP method of weighed value determination. Table 3-4 represents the binary comparison matrix. The binary comparison method represents the importance of key facilities in a quantitative fashion, allowing the side-by-side comparison of key facilities in order to calculate the weighed value.

<Table 3-4> Binary comparison matrix(Level 1)

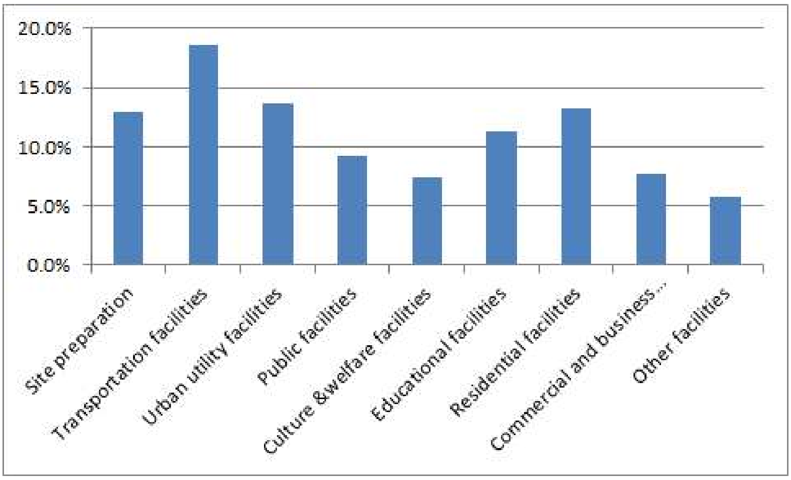
Type	Site preparation	Transportation facilities	Urban utility facilities	Public facilities	Culture & welfare facilities	Educ-ational facilities	Resi-dential facilities	Comm-ercial and business facilities	Other facilities
Site preparation	1								
Transportation facilities		1							
Urban utility facilities			1						
Public facilities				1					
Culture & welfare facilities					1				
Educational facilities						1			
Residential facilities							1		
Commercial business facilities								1	
Other facilities									1

As shown on Table 3-5, weighed value for the 9 key facilities are: 0.129 for site preparation facilities, 0.187 for transportation facilities, 0.137 for urban utility facilities, 0.093 for public facilities, 0.074 for culture & welfare facilities, 0.113 for educational facilities, 0.132 for residential facilities, 0.078 for commercial and business facilities, and 0.057 for other facilities. For AHP importance value, percentage, and rank, transportation facilities took the top, followed by urban utility facilities, site preparation facilities, residential facilities, educational facilities, public facilities, commercial and business facilities, culture & welfare facilities, and other facilities.

<Table 3-5> Key facilities in the order of importance

Importance factors	AHP importance value	Percentage(%)	Rank
Site preparation	0.129	12.9	3
Transportation facilities	0.187	18.7	1
Urban utility facilities	0.137	13.7	2
Public facilities	0.093	9.3	6
Culture & welfare facilities	0.074	7.4	8
Educational facilities	0.113	11.3	5
Residential facilities	0.132	13.2	4
Commercial and business facilities	0.078	7.8	7
Other facilities	0.057	5.7	9

Figure 3-8 is a visualization of Table 3-5.



<Figure 3-8> Importance of key facilities

(3) Consistency analysis[32)]

The key facility weighed value obtained through AHP is a product of subjective assessment. Thus, a consistency analysis of data is necessary. Therefore, the Consistency Ratio(CR) values were calculated for each survey sheet in order to verify the values obtained through AHP analysis. The CR is a division of Consistency Index(CI) by Random Index(RI), an average random index obtained empirically.

The CI is calculated using the following formula.

$$CI = (\lambda - n) / (n - 1)$$

λ : average of the value obtained through dividing the aggregated importance value with the Importance Index

n : number of subjects being compared

The CR is calculated using the following formula.

$$CR = CI / RI$$

The CI value for this survey was 0.1428, and the RI value at n=9 was 1.45. Thus, the CR value was 0.0985. Generally, results of a survey is considered to be significant if the CR is under 10%[33)]. Therefore, it is determined that the results of this survey is significant.

32) Kim, Sae Hun, Modern Management Science, pp.221~230, Muyok Publishing, 2010.
33) Satty, T. L., The analytic hierarchy process, McGraw-Hill, 1980

3.3.2 Weighing of subordinate facilities to key facilities

The weighing criteria for Level 2 subordinate facilities are to be applied while reflecting the properties of each subordinate facility. Level structure for key and subordinate facilities was done as per the Work Breakdown Structure. Weighing criteria of subordinate facilities(Level 2) to key facilities is as follows.

(1) Site preparation facilities

Site preparation facilities are comprised of groundwork, landscaping, demolition, artifact excavation, etc. Demolition and artifact excavation must be completed prior to groundwork, and their properties are not consistent with a construction activity. Thus, they are excluded from progress measurement process. In this study, the area of landscaping as a percentage of site preparation is designated as the weighed value between two subordinate facilities.

(2) Transportation facilities

Transportation facilities include municipal roads for connecting key regions, public transit roads for comfortable urban transit, outside ring roads for circulating traffic, approach roads, and urban transit roads. In this study, physically completed length of road as a percentage of total road length is designated as the weighed value among the subordinate facilities of the transportation facilities.

(3) Urban utility facilities

Urban utility facilities are critical to daily lives of a city's residents. They include electric/gas/heating/communications facilities, water treatment facilities, waste management facilities, and landfills.

In this study, due to the difficulty in determining a single, unified weighed value for subordinate facilities while reflecting their properties, the weighed value of subordinate facilities under urban utility facilities is determined based on project costs.

(4) Public facilities

Public facilities include central administration facilities, national administration facilities, regional administration facilities, and government-funded research institutions. Central administration facilities include government buildings and administrative support centers, national administration facilities include courts and prosecutor's offices, and regional administrative facilities include city halls, boards of educations, and fire stations. In this study, the sum of the total Floor Areas of all subordinate facilities is designated as the weighed value of subordinate facilities under public facilities.

(5) Culture & welfare facilities

Culture & welfare facilities are aimed at providing culture and welfare to the residents, and include community complexes, welfare support centers, spots complexes, and arts centers. In this study, the sum of the total Floor Areas of all subordinate facilities is designated as the weighed value of subordinate facilities under culture & welfare facilities.

(6) Educational facilities

Educational facilities are placed in each region and they include kindergartens, elementary/middle/high schools, and universities. In this study, the sum of the total floor areas of all schools is designated as the weighed value of subordinate facilities under educational facilities.

(7) Residential facilities

Progress rate for residential facilities in large-scale cities is determined based on multi/single-family housing within the residential zone. In progress measurement of residential facilities, the area of each units within multi-family housing buildings is reflected, instead of relying solely on the number of housing units.

The progress rate for a city's residential facilities can be measured by simply calculating the number of completed units as a percentage of total number of planned units. However, in large-scale city construction projects, residential facility construction tends to come in massive batches after the completion of site preparation. Thus, units under construction must be included. This allows the designation of weighed value of each units as compared to the area of all planned housing units, and the measurement of each unit's progress as a percentage of total area. Also, the percentage of units under construction vs. units completed can be calculated to review the trend of housing unit construction. This index effectively reflects the properties of residential facilities and thus allows for the measurement of execution performance and prediction of future trends.

(8) Commercial and business facilities

Commercial and business facilities support the city's self-sufficiency, create employment, provide convenience to residents, and vitalize the city. They include hotels, convention centers, supermarkets, and other retail, commercial, and business facilities. As commercial and business facilities are often co-located in the same building, the weighed value for such facilities is designated as a single group. In this study, the sum of the total floor areas of all subordinate facilities is designated as the weighed value of subordinate facilities under commercial and business facilities.

(9) Other facilities

Other facilities are often placed by region and include, medical facilities, religious facilities, gas stations, and funeral homes. In this study, the sum of the total Floor Areas of all subordinate facilities is designated as the weighed value of subordinate facilities under other facilities. Figure 3-6 represents a summary of weighed value designation criteria for subordinate facilities.

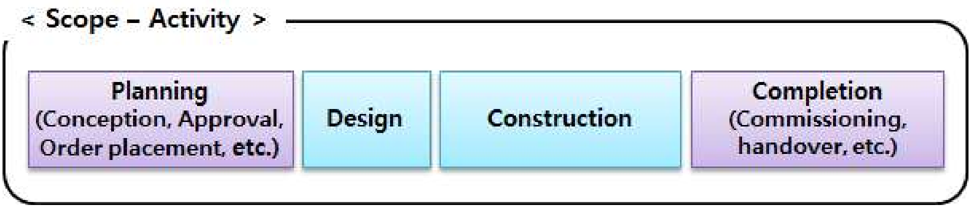
<Table 3-6> Weighing criteria for facilities subordinate to 9 key facilities

Key facilities(Lev.1)	Subordinate facilities	Weighed value designation criteria	Notes
Site preparation	Groundwork, landscaping, etc.	Total area	
Transportation facilities	Municipal roads, outside ring roads, bridges, etc.	Length	
Urban utility facilities	Clean Net, water treatment centers, waste management facilities, etc.	Cost	
Public facilities	Public buildings, city halls, boards of education, etc.	Total Floor Area	
Culture & welfare facilities	Community complexes, culture facilities, etc.	Total Floor Area	
Educational facilities	Kindergartens, elementary/middle/high schools, universities, etc.	Total Floor Area	
Residential facilities	Multi/single-family housing, etc.	Total Floor Area	
Commercial and business facilities	Retail areas, commercial complexes, etc.	Total Floor Area	
Other facilities	Religious, medical, refueling facilities, etc.	Total Floor Area	

The ANS, developed using WBS, project developers, etc., as a basis, is used for basic information input. The level of input will differ depending on the properties of each key facilities. Contract units such as design and construction are entered as basic information. Thus, weighed value such as design and construction for certain facility will be determined based on the facility's properties, in order to ensure that weighed value of each contract unit will be aggregated to the higher level in an effective manner. The following section provides the weighing criteria for contract units.

3.3.3 Weighing criteria for contract units of key facilities

Major contract units for construction projects can be categorized as design contracts and construction contracts. They are comprised of planning that includes conceptualization, approval, and order placement, as well as construction, completion, and hand-over.



<Figure 3-9> Construction project stages

Generally, contract units such as design, construction, commissioning are integrated in the progress management of construction projects. While approval prior to design and order placement prior to construction are very much important, little costs is assigned that way and they are thus excluded from progress management. This study incorporates such contract units as they are deemed necessary for progress management of construction projects.

Contracting for facility construction mainly consists of civil and architectural work, which includes service contracts such as design and construction contracts. For urban utility facilities that have large machinery, purchasing and commissioning tasks are included in service and construction contracts. In order to efficiently ascertain the actual progress rate of key facilities, it is necessary to determine the weighed values the planning, design, construction, procurement(if necessary), and commissioning(if necessary) stages of each facility.

(1) Weighed value status of contract units for large national level projects

Methods used in large national level projects conducted in Korea are reviewed in order to determine the weighed value of contract units of key facilities. National level projects reviewed are: road and thermal power plant construction project by the Korea Expressway Corporation; Korea Train express project by the Korea Rail Network Authority[34] ; Incheon International Airport(Phase 1)[35] project by the Incheon International Airport Corporation; and nuclear power plant construction project by Korea Hydro & Nuclear Power. Some of the above saw the application of confirmed weighed value for contract stages. Table 3-7 shows some of the highlights.

34) Korea Train Express, Project Management Procedure, S-26
35) Incheon International Airport Construction Corporation, Construction Schedule Procedure, Schedule-08, p.3

<Table 3-7> Stage-by-stage weighing for major national projects in Korea

Type	Korea Expressway Corporation		Nuclear power plant		Thermal power plant		Korea Train express		Incheon International Airport (Phase 1)	
	A	B	A	B	A	B	A	B	A	B
Compe-nsation	19.8	19.8	-	-	-	-	8.3	8.3	8.9	10.0
Design	0.6	0.6	9.5	15.0	3.6	20.0	1.8	1.8	3.5	10.0
Supervi-sion	1.6	1.6	-	-	-	-	0.5	0.5	5.1	0.0
Purchas-ing	-	-	60.0	20.0	63.9	30.0	13.1	13.1	-	-
Ordering	-	-	-	-	-	-	-	-	-	5.0
Constru-ction	78.0	78.0	29.0	60.0	32.0	45.0	76.3	76.3	82.3	73.0
commis-sioning	-	-	1.5	5.0	0.5	5.0	-	-	0.2	2.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* A: Project cost weighed value(%), B: Applied weighed value(%)

In the Table 3-7 above, the weighed value for each stages of the Korea Train express and road construction projects are determined through project costs. However, in nuclear and thermal power plant projects and the Incheon International Airport project, weighed value for each stage is determined through the reflection of its importance, taking the unique properties of each project into consideration.

- Ordering Stage

For the Incheon International Airport project, order placement during the course of the construction stage affect follow-up tasks a great deal. Thus, a unique feature of this project is that the order placement is given a weighed value even though no budget was included in the ordering stage. The weighed value of the order placement task is equal to those of supervisory cost and overall project management cost.

- Design Stage

The design cost of the nuclear power plant is 9.5% of the total budget, while its weighed value is 15.0%, whereas the design cost of the thermal power plant is 3.6% of the total budget, while its weighed value is 20.0%. The design cost of the Incheon International Airport is 3.5% of the total budget, while its weighed value is 10.0%.

- Purchasing Stage

For nuclear and thermal power plant projects, the weighed value of the purchasing stage was reduced compared to its share of the budget. The purchasing cost of the nuclear power plant is 60.0% of the total budget, while its weighed value is 20.0%, whereas the purchasing cost of the thermal power plant is 63.9% of the total budget, while its weighed value is 30%.

- Construction Stage

The construction cost of the nuclear and thermal power plant projects are 29% and 32% of the total budget respectively. Due to the importance of construction for power plants, however, the weighed value of the construction stage was increased to 60% and 45% respectively. For the Incheon International Airport project, the construction cost was 82.3% of the overall budget and its weighed value is 73.0%. This is due to the fact that large machinery such as the luggage processing system and the refueling system were included in the construction stage instead of the purchasing stage.

- Commissioning Stage

For nuclear and thermal power plant projects and the Incheon International Airport project, the weighed value of the commissioning stage was increased compared to its share of the overall budget due to the importance of commissioning for these projects. The commissioning costs of the nuclear and thermal power plant projects are 1.5% and 0.5% of the total budget respectively, but their weighed values are both 5%. For the Incheon International Airport project, the commissioning cost is 0.2% of the overall budget, but its weighed value is 2.0%.

- Comparison of budget share and Determined weighed value

The review of weighed value determination for each stage revealed that while the budget share method is used more commonly, certain projects such as the nuclear and thermal power plant projects and the Incheon International Airport project use a more nuanced method of taking the importance of each stage into consideration. Table 3-8 shows the pros and cons of these methods.

<Table 3-8> Advantages and disadvantages of the stage-by-stage weighing method

Type	Budget share method	Determined weighed value for each stage method	Notes
Pros	■ Common method ■ Simplicity aids understanding	■ Able to measure progress in a more reasonable manner, taking into consideration factors such as importance for each stage ■ Minimum changes to the progress after changes to the project cost	
Cons	■ Progress will change after changes to the project cost ■ Factors such as importance are not reflected in progress measurement	■ Separation of budget execution and progress rate may cause confusion	

As shown on Table 3-8, while the simplicity of the budget share method allows for easy understanding, it does not reflect the importance of each stage and project duration. Also, any changes to the budget affects the progress rate. The determined weighed value method allows for more reasonable progress measurement compared to the budget share method as it takes into consideration factors such as the importance of each stage and the project duration. However, the separation of budget execution and the lack of understanding may result in confusion.

(2) Weighing of contract units in a large-scale city construction project

In this study, the progress measurement method used in nuclear and thermal power plant projects and the Incheon International Airport project will be utilized, taking into consideration factors such as the importance of each stage, while clearly distinguishing the progress measurement with the budget execution in order to prevent confusion and to provide a more reasonable progress measurement for each stage. The weighing criteria for these contract units' progress by stage is as follows.

First, land compensation is excluded from progress measurement as it is the characteristic of large-scale cities to have land compensation paid for in advance by government agencies or project developers.

Second, the determined weighed value for each stage, instead of simple budget share, will be applied in order to prevent any changes to the budget from affecting the progress rate.

Third, while the order placement task of the construction stage does not incur any costs, it has significant impact on the overall schedule. Thus, a certain level of weighed value is to be assigned to the task in order to foster expeditious order placement.

Fourth, services excluding the design, such as the construction cost of distributable direct expense, are to be excluded from the progress measurement.

The weighed value determination for each stage of contract units must reflect the properties of each key facility.

- Ordering Stage

While the ordering task is not reflected in the costs, the task is to be given a weighed value of 5%(same as that of the Incheon International Airport project) as it has significant impact in the following tasks.

- Design Stage

Based on previous large-scale city construction projects in Korea and the Incheon International Airport project, as well as expert feedback, the weighed value for the designing stage is to be 10% of the facility weighed value.

- Procurement Stage

The weighed value of the procurement stage, considering the impact of large machinery on the follow-up tasks, will be only applied to contracts pertaining to urban utility facilities. The weighed value of the procurement stage of urban utility facilities for large-scale cities, determined while taking into consideration those of the thermal and nuclear power plant projects, previous large-scale city construction projects, as well as expert feedback, is set to 25%.

- Construction Stage

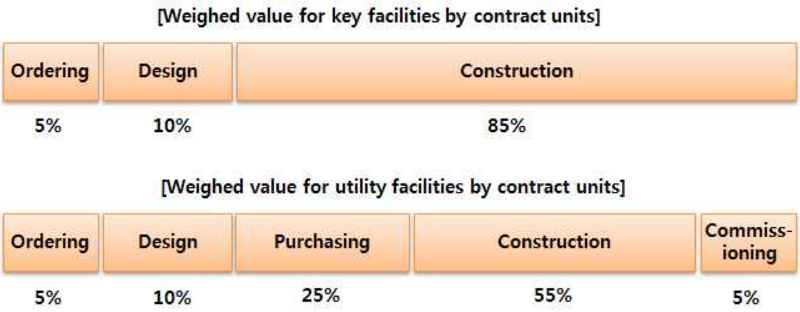
The weighed value for the construction stage shall be the remaining value after excluding those of ordering, design, and commissioning stages.

- Commissioning Stage

In terms of the commissioning stage, it is not considered in most facilities with the exception of a few urban utility facilities. Generally, the cost incurred by commissioning runs of construction machinery are included in the construction stage, and the cost is only distinguished in facilities such as Combined Heat & Power Generation Plants in which commissioning runs are critical due to the existence of large machineries. The weighed value for the commissioning stage in Combined Heat & Power Generation Plants is set to 5%(same as that of the nuclear power plant). For other utility facilities, the budget share of commissioning cost is in the range of 0.4~1.2%. However, due to the facilities' similarity in composition with the Incheon International Airport and taking into consideration expert feedback, the weighed value of the commissioning stage is set to 2%, same as that of the Incheon International Airport.

■ Weighing at the Contracting Stage

Figure 3-10 provides a summary of weighing criteria for contract units.



<Figure 3-10> Weighed value of Contract Units

The weighed values for contract units pertaining to facilities except urban utility facilities are: ordering 5%, design 10%, construction 85%. For urban utility facilities: ordering 5%, design 10%, procurement 25%, construction 55%, commissioning 5%. Upon determination of weighed value for design, construction, ordering, procurement, and commissioning stages of each key facility, Control Points must be established for each stage in an impartial and reasonable manner in order to review and confirm actual performance. The next section provides a discussion on the method of establishing impartial and reasonable control points.

3.3.4 Designation of Control Points for each stages

In order to perform an objective assessment of completed tasks, a systematic and reasonable method must be established between the owner and the contractor. In a few contracts signed in Korea, as well as most of Engineering Procurement Construction contracts overseas, standards for execution performance of the EPC contractor are defined and agreed upon. For design, purchasing, and order placement, Control Points are established for each step and weighed values are assigned in order to measure performance, whereas a representative quantity is designated based on key quantities in order to assess performance in the construction stage. Control Points for design, purchasing, and order placement, in addition to the representative quantities for construction, form the basis of basic information that allows for reasonable and objective application of the EVM. Documents from EPC projects overseas and nuclear power plant construction projects in Korea were consulted, and characteristics of large-scale city construction project were reflected in order to establish Control Points and weighed values for the design and purchasing stages.

(1) Ordering Stage

While the ordering stage is not reflected in the overall cost in large-scale city construction projects, it can be safely said that the stage has great influence in follow-up tasks. As the order placement task affects the entire project, several cases of large-scale national projects were consulted, and experts feedback and characteristics of large-scale city construction projects were reflected, in order to establish weighed values for each stages. Table 3-9 is a representation of the result.

<Table 3-9> Control points for the Ordering Stage

Type	Stage	Control Point	Weighed	Weighed total
Ordering	Step 1	Bidding invitation	50%	50%
	Step 2	Bidder selection	40%	90%
	Step 3	Contract signing and commencement	10%	100%

(2) Design Stage

As for the design stage of the nuclear power plant project, control points and weighed values were disparate between functional areas (i.e. civil engineering, construction, etc.). Thus, in previous projects, 7 to 8 control points were established with weighed values being designated for each. However, due to international export of nuclear power plant construction projects, as well as to ensure effective management of projects in Korea, the number of control points was reduced to 3(submission for approval, submission for construction, final submission). Jo, Hong Yeon[36], in his research of petroleum EPC projects overseas, found that 3 control points(design commencement, submission for approval, and submission for construction) were established during the design stage. For EPC thermal power plant construction project by firm "H," control points during the design stage included submission for approval, submission for construction, and final submission, in addition to design commencement, internal review, and feedback application. In this study, literature pertaining to control points, documents from overseas petroleum and thermal plant EPC projects, as well as the nuclear power plant construction

36) Jo, Hong Yeon, A Standard Method for Progress Measurement in a Petrochemical Plant Project, Hanyang University masters dissertation, 2011.

project in Korea were consulted in order to establish control points and corresponding weighed values as shown on Table 3-10.

<Table 3-10> Control points for the Design Stage

Type	Stage	Control Point	Weighed	Weighed total
Design	Step 1	Submission for approval	30%	30%
	Step 2	Submission for construction	50%	80%
	Step 3	Final submission	20%	100%

Design contracts for large-scale city construction projects have 3 control points as shown on Table 3-10. The weighed value for the Submission for approval is 30%, followed by 50% for the Submission for construction, and 20% for the final submission.

(3) Purchasing Stage

For procurement stage, main tasks generally include supplier designation, manufacture completion, shipping/transport, and delivery. Control Points for overseas EPC projects during the purchasing stage are similar to those of petroleum EPC projects by firm S, power plant EPC project by firm H, and nuclear power plant construction project in Korea. However, weighed values for each stage were observed to be disparate for each contract. In the context of large-scale city construction projects, the procurement stage is only relevant for a handful of urban utility facilities. Individual projects that fit this criteria include the clean net facility construction project and water treatment center construction project, etc. Thus, properties of urban utility facility construction projects during the procurement stage were reflected, and papers pertaining of control points, documents from overseas petroleum and thermal plant EPC projects, as well as the nuclear power plant construction project in Korea were consulted, in order to establish control points for the purchasing stage as shown on Table 3-11.

<Table 3-11> Control points for the Purchasing Stage

Type	Stage	Control Point	Weighed	Weighed total
Purchasing	Step 1	Order placement	35%	35%
	Step 2	Manufacture and inspection	50%	85%
	Step 3	Transportation and delivery	15%	100%

As shown on Table 3-11, 3 control points are established for the purchasing stage. The weighed value for order placement is 35%, followed by 50% for manufacture and inspection, and 15% for transportation and delivery.

(4) Construction Stage

The progress rate of construction is calculated using physical measurement units after selecting a representative quantity based on key tasks listed in projected schedules of each contractors. The weighed value for each activity is multiplied to the measurement in order to obtain the progress rate. Construction efforts for large-scale city construction projects include civil engineering tasks such as construction of infrastructure, roads, and landscaping, as well as facility construction of government-funded research centers, public housing, business facilities, urban utility facilities, and other facilities. The representative quantity for each contract in regards to the above projects are selected by reflecting expert and action-level personnel feedback and comments.

(5) Commissioning Stage

In large-scale city construction projects, commissioning occur in urban utility facilities such as clean net and water treatment centers, etc. Electrical and mechanical facilities for general facilities such as government and residential buildings are included in the construction stage. For clean net, advance inspection and testing takes 20 days, with 90 days for integrated commissioning which includes 50 days for no stress operation and 40 days for stress operation. For water treatment centers, the integrated commissioning takes a total of 180 days, and a series of tests and commissioning including water pressure test must be completed. Control points and corresponding weighed values for commissioning in urban utility facilities for large-scale cities were established after reflecting the characteristics of large-scale city construction projects and expert comments, as well as consulting pertinent literature as shown on Table 3-12.

<Table 3-12> Control points for the Commissioning Stage

Type	Stage	Control Point	Weighed	Weighed total
commissioning	Step 1	Advance inspection and test commencement	30%	30%
	Step 2	Integrated commissioning commencement	50%	80%
	Step 3	Integrated commissioning conclusion	20%	100%

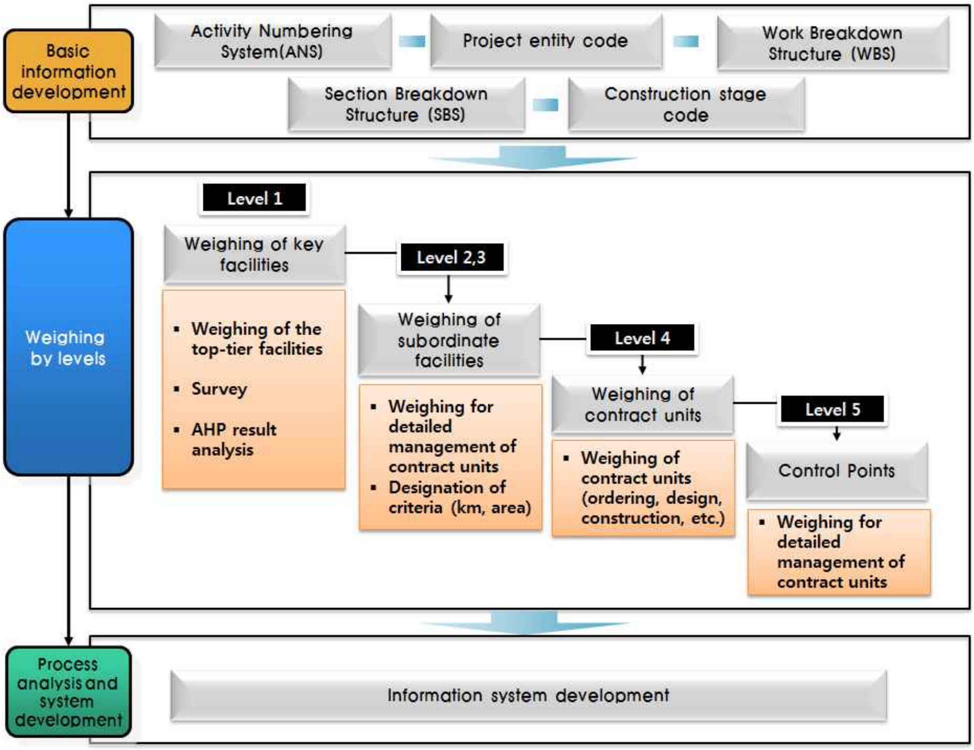
3 control points were established for the commissioning stage, with weighed value for the advance inspection and test commencement at 30%, followed by 50% for the integrated commissioning operation

commencement, and 20% for the integrated commissioning operation conclusion.

Through measurement of performance through appropriate control points or representative quantities, as well as progress measurement of each key facility and the large-scale city overall, it is possible to establish an environment that ensures rapid reaction and response to any delays in any facilities.

3.4 Progress Management model proposition for a large-scale city construction project

This study proposed a model of the progress management for large-scale city construction project as following Figure 3-11.



<Figure 3-11> Progress Management model for large-scale city construction projects

As shown on Figure 3-11, it is the intention of this study to develop basic information, designate key facilities and corresponding activities, determine weighed values for each facilities and Activities, as well as standard quantity(area, total floor area, length, project cost, etc.), and to establish control points for each stage of all activities. Using these as the basic building block, an information system for progress management is developed in order to propose effective and systematic progress management methods for city construction projects.

Chapter 4. Case study

4.1 The S-City

4.1.1 Case overview

The S-City is part of the Korean government's policy to relocate government agencies and national research institutions, etc., away from overly dense capital region. Located in the central region of Korea, 120km away from Seoul, 10km away from Daejon and Cheongju, 24km away from Cheongju airport, and 20km away from Ohsong KTX station, the S-City has a projected total area of 72.91 ㎢, with 223㎢of surrounding areas. The objective of the S-City project is a population of 300,000 by 2020, and population of 500,000 by 2030[37].

Of 72.91㎢ of S-City's total area, green areas take up 52.2%, followed by 22.5% for public facilities, 20.7% for residential areas, and 2.0% for commercial areas. The objectives of the project is to enhance national competitiveness through balanced national development by creating a world-class, environmentally-friendly, self-sufficient administrative city that combines culture and latest information technology to create a human-centric environment. Also, the city is designed with the ring structure, divided into 6 living areas: central administration area, cultural and international exchange area, municipal administration area, higher education and research area, medical and welfare area, and information technology area.

In order to construct various facilities including government

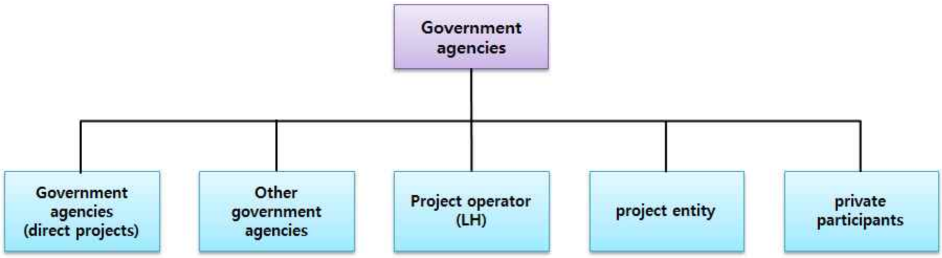
37) National Agency for Administrative City Construction, Administrative City Construction Integrated Project Management Detailed Execution Plan, p.2, 2008.

buildings, roads, and electrical infrastructure, numerous project entities are currently participating in the S-City project. Lines of effort include direct order government projects, developer projects, and private endeavors such as construction of educational, residential, and commercial facilities. A government agency is a lead agency for this project as serves as a control tower to manage and coordinate all lines of effort. Figure 4-1 represents the government agency's organization structure.

<Figure 4-1> Organization of the Government Agency

The government agency is comprised of 4 bureaus, 14 divisions, and 4 teams, and serves as an agency that places all orders for direct order government programs, in addition to its function as the control tower for the entire project. The project coordination team is the lead office for the management and coordination of the entire project.

Figure 4-2 represents the breakdown of participating entities for the project.

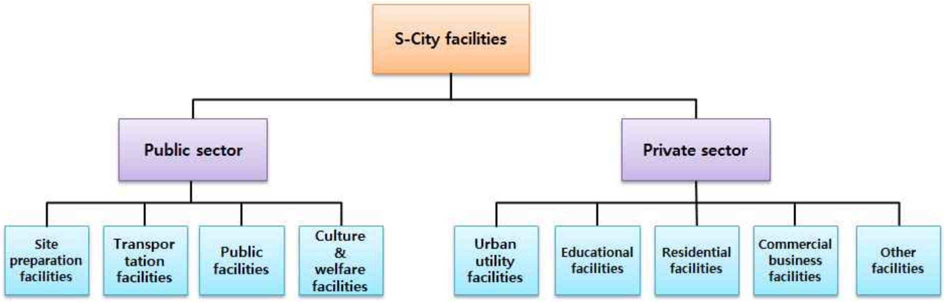


<Figure 4-2> Participating entities for the S-City project

Government agency direct order projects include construction projects for key administrative buildings such as Sejong city hall, administrative support center, and presidential archives, as well as key road networks such as connection to Daeduk techno valley. Other government agency projects include stage 1~3 project for the government office building led by the Ministry of Government Administration and Home Affairs, and school construction project led by the Ministry of Education. Projects led by the project developer include the construction of urban transportation facilities, environmental facilities, landscapes, and other structures. While the government agency is the supervisory agency for urban utility facilities, the project itself is conducted through cooperation between the government agency and pertinent contractors. Major private investment projects include the construction of large-scale commercial buildings and business facilities, etc.

4.1.2 Breakdown of the S-City project

As shown on Figure 4-3, the S-City project can be broken down into the public and private components.



<Figure 4-3> Key facilities of the S-City project

The public component is funded by the government's project cost of 22.5 trillion KRW, and it includes site preparation, transportation facilities, public facilities, and culture & welfare facilities. It is comprised of government agency direct order projects and projects ordered by other government agencies and the project developer. The private component exists outside of the government's project cost, and it includes urban utility facilities, educational facilities, and commercial facilities, etc. A realistic and complete measure of the city's completion can only be obtained through the reflection of actual progress rates of both components.

(1) Public component projects

The public component of the project can be broken down into four key fields. These include, as shown on Table 4-1, site preparation such as groundwork and landscaping, transportation facilities such as metropolitan roads, bridges, and urban transit roads, and public facilities such as government offices and research institutions, culture

& welfare facilities such as community complexes and arts centers.

<Table 4-1> Public sector facilities

Type		Facilities	Notes
Public	Site preparation	Groundwork, landscaping, etc.	
	Transportation facilities	Metropolitan roads, urban roads, etc.	
	Public facilities	Government offices, research institutions, etc.	
	Culture & welfare facilities	Welfare, sports facilities, etc.	

For the S-City, monthly and yearly budget execution performance rates are measured as a percentage of the total project cost of 22.5 trillion KRW, and the large-scale city progress rate is measured using a budget of 15.4 trillion KRW(total budget minus land compensation) as a basis.

(2) Private component projects

The private component of the project can be broken down into 5 key fields. These include, as shown on Table 4-2, urban utility facilities such as electricity, gas, heating, communications facilities, educational facilities such as kindergartens and elementary/middle/high schools, residential facilities such as multi/single-family housing, commercial & business facilities such as large-scale retail complexes, and other facilities such as medical and religious facilities. Therefore, it is reasonable to conclude that numerous private facilities comprise a city in addition to public facilities, and their importance is quite significant. It is necessary to manage the progress of private facilities and continuously track any developments, as such facilities have a significant impact in the improvement of a city's living conditions and initial population influx.

<Table 4-2> Private sector facilities

Type		Facilities	Notes
Private	Urban utility facilities	Electricity, gas, heating, communications, etc.	
	Educational facilities	Kindergartens, elementary/middle/high schools, universities, etc.	
	Residential facilities	Multi/single-family housing, etc.	
	Commercial and business facilities	Commercial facilities, neighborhood facilities, etc.	
	Other facilities	Gas stations, parking spaces, funeral homes, hospitals, industrial facilities, etc.	

It is the intention of this study to apply a separate set of weighed values for each private facilities as their impact on the development of the S-City must be fully appreciated. This enables the measurement of a separate set of progress rates for private facilities, and ultimately, the measurement of S-City's actual rate of completion.

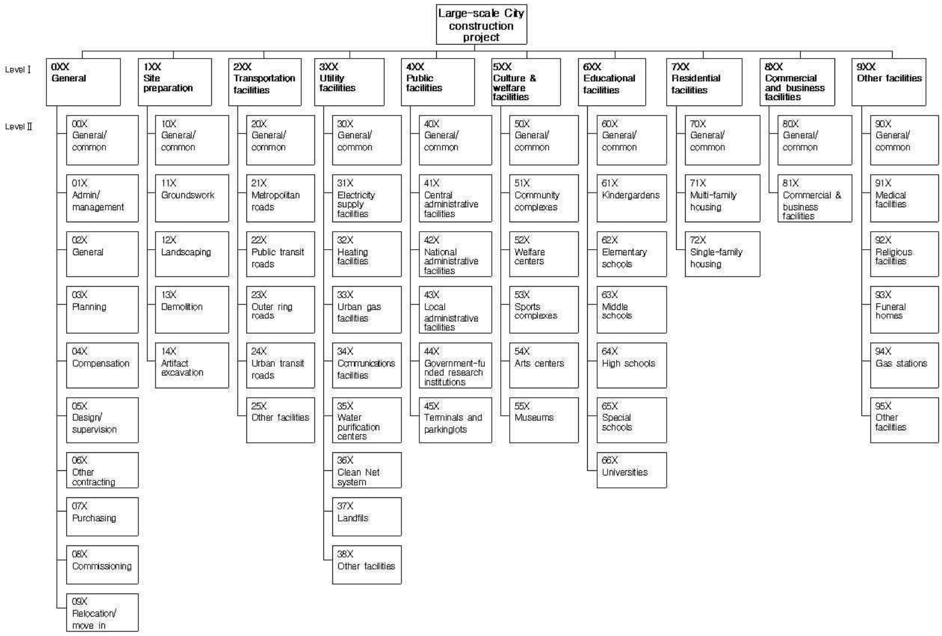
4.1.3 Basic information for establishing a Progress Management of S-City

The S-City is comprised of key facilities(site preparation facilities, transportation facilities, urban utility facilities, public facilities, and residential facilities, etc.) and stakeholders(government agency, project developer, contractors, and private participants). Detailed information must be collected for each facility and stakeholder, and such information must be tiered and summarized. As shown on Figure 4-2 participating entities for the S-City project and Figure 4-3 Key facilities of the S-City project, the progress rate must be summarized and aggregated by each facility and stakeholder, and construction stage. To that end, elements mentioned earlier in 3.3 will be applied to the S-City project. A Work Breakdown Structure of the city's facilities was developed, and an Activity Numbering System that displays the progress rate under the standardized numbering system was applied.

(1) Development of Work Breakdown Structure

In order to obtain a realistic understanding of construction status of key facilities that comprise the S-City, it is necessary to establish a overall progress rate that systematically reflects complex characteristics of the city's facilities, as mentioned above in 3.1. The progress rate must reflect the progress of the city as a whole, integrating not only the progress rate of each activity, but also shares by the government, project developer, contractors, and key private participants. To that end, a Work Breakdown Structure was developed in order to establish the progress rate of the project with each activity serving as a basis.

Key facilities that comprise of the city include site preparation facilities, transportation facilities, urban utility facilities, public facilities, and residential facilities. Figure 4-4 shows the leveling structure of the WBS.



<Figure 4-4> Work Breakdown Structure Level 1 & Level 2

The WBS is structured in a hierarchical manner, with 3 levels (see Addendum 3). Details on Level 1 are as follows.

- 0XX General

General management, administration, project management, planning, compensation, design, supervision, research, investigation, etc.

- 1XX Site preparation facilities

Groundwork, landscaping, demolition, artifact excavation, etc.

- 2XX Transportation facilities

Roads and bridges constructed as part of the project. Excludes roads ordered as part of the site preparation work.

- 3XX Urban utility facilities

Electricity supply facilities, heating facilities, Urban gas facilities, Communications facilities, Water purification centers, Clean Net system, Landfills, etc.

- 4XX Public facilities

Central administrative facilities, National administrative facilities, Local administrative facilities, Government-funded research institutions, etc.

- 5XX Culture & welfare facilities

Community complexes, Welfare centers, Sports complexes, Arts centers, Museums, etc.

- 6XX Educational facilities

Kindergartens, Elementary schools, Middle schools, High schools, Special schools, Universities, etc.

- 7XX Residential facilities

Multi-family housing, Single-family housing, etc.

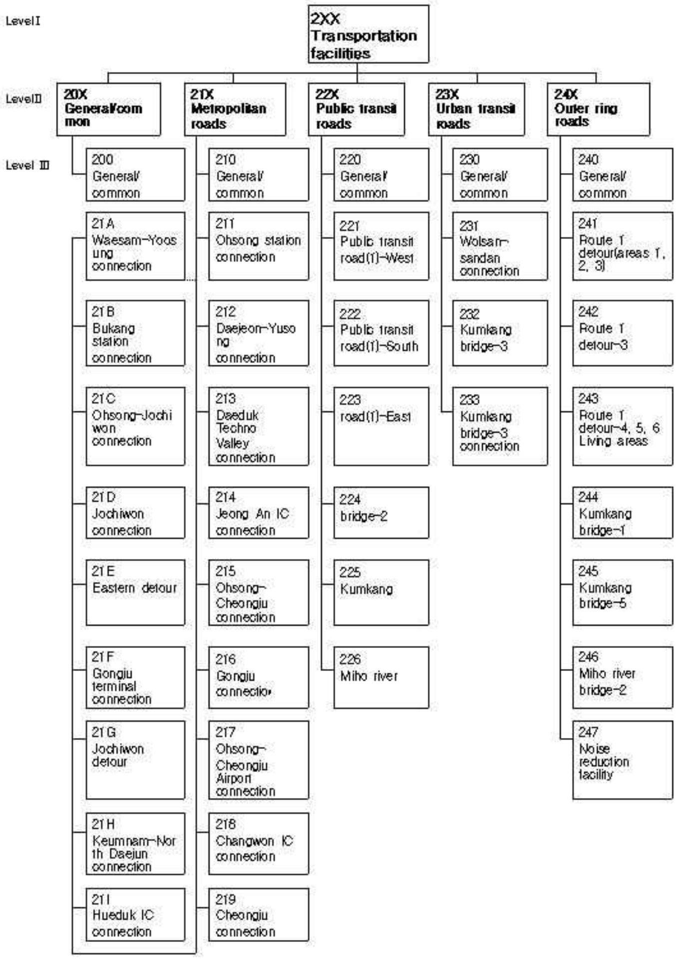
- 8XX Commercial &business facilities

Retail areas, Department stores, Commercial complexes, Business facilities, etc.

- 9XX Other facilities

Medical facilities, Religious facilities, Funeral homes, Gas stations, etc.

Level 2 facilities are subordinate to Level 1, and Level 3 facilities are subordinate to Level 2. Figure 4-5 shows the composition of Level 2 and 3 facilities under 2XX Transportation facilities.



<Figure 4-5> Work Breakdown Structure for the transportation facilities Level 2 & Level 3

- 20X General/common

General administration, common functions of transportation facilities, etc.

- 21X Metropolitan roads

Includes metropolitan roads such as Ohsong station connection road

▪ 22X Public transit roads

Public transit roads, key bridges, etc.

▪ 23X Urban transit roads

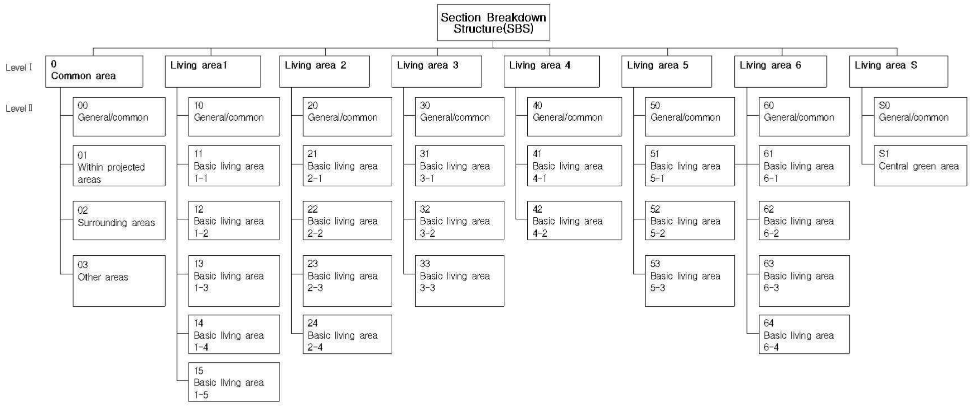
Includes urban transit roads that are not part of Site preparation

▪ 24X Outer ring roads

Includes Outer ring roads(north and south), Route 1 detour, etc.

(2) Section Breakdown Structure development

Since S-City is planned and being constructed by basic living areas, it is necessary to manage the S-City project in a systematic manner through categorization of its sections by basic living areas. In this study, SBS numbers are incorporated into the WBS in order to maximize its clarity. The SBS categorizes living areas based on the S-City development plan, and also adds common area codes that can be applied to common infrastructure shared by multiple living areas. Living areas in each sections are further divided into basic living areas. Figure 4-6 represents an overview of the SBS.



<Figure 4-6> Breakdown of the Section Numbering Structure

The SBS is comprised of Levels 1(greater living area) and 2 (basic living area). A breakdown of Level 1 is as follows.

- 0 : common area

Areas excluded from living areas 1 to 6, or those shared by those living areas.

- 1 : living area 1

Central administrative area that includes a few residential facilities

- 2 : living area 2

Cultural/international exchange area that hosts key culture and international exchange facilities

- 3 : living area 3

Municipal administrative area that includes residential and commercial facilities

- 4 : living area 4

Academic and research area that hosts RANN(Research Applied to National Needs) complex, government-funded research institutions, and universities

- 5 : living area 5

Medical and welfare area that hosts medical and welfare facilities

- 6 : living area 6

High-tech knowledge-based area that hosts high-tech industrial institutions and firms

- S : living area S

Central green area that hosts the central park and arboretum

The living area 2, which is classified as a Cultural/International Exchange Area under the Urban Classification System, is divided into following basic living areas.

- 20X :General/common

Area shared by 2-series living areas

- 21 : living area 2 - 1

Basic living area 2-1

- 22 : living area 2 - 2

Basic living area 2-2

- 23 : living area 2-3

Basic living area 2-3

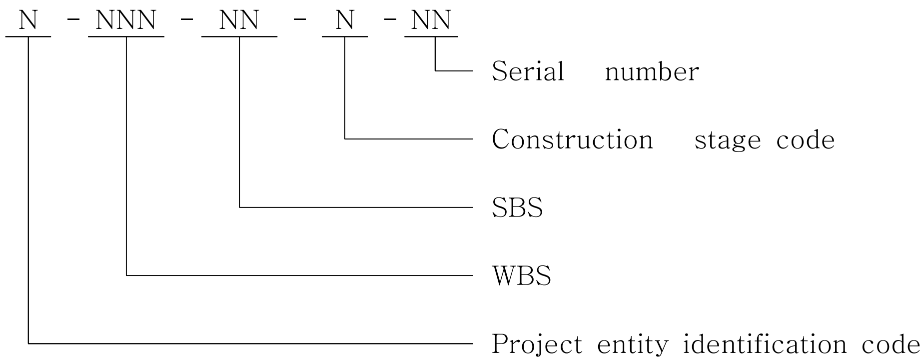
- 24 : living area 2-4

Basic living area 2-4

(3) Development of Activity Numbering Structure(ANS)

In order to enable prediction and analysis in the future through progress and performance assessment of progress by region and key facilities, as well as to integrate the WBS and SBS for the purpose of application in large-scale city construction projects, an Activity Numbering System(ANS) is developed as part of this study.

The ANS incorporates management/facility/functional properties, as well as regional properties, which is a significant element in the case of S-City. Management properties of ANS for the S-City refer to project participants such as contractors, project developer, and private firms, whereas facility properties refer to unique properties of each facilities. Regional properties refer to the basic living areas where a facility is located in, and functional properties refer to functions such as design and construction. Using the aforementioned principles and basic concepts as a basis, the ANS establishes a unique numbering system for each activity, and connects pertinent information to the upper level for each living area and project participant. It also supports efficient managerial decision-making as needed through accurate and expedient status tracking based on information that is promulgated upward. Figure 4-7 shows the structure of the ANS that reflects management/facility/regional/functional properties.



<Figure 4-7> Breakdown of the Activity Numbering System

As shown on Figure 4-7 above, the ANS is comprised of project entity identification codes, construction stage codes, serial numbers, as well as the WBS and SBS. The project entity identification code distinguishes between the Government Agency, other government agencies, project developer, individual contractors, and private firms. The WBS arranges facilities in under a hierarchical structure, and displays the connective structure down to the detailed activity level. The purpose of the SBS is to categorize and apply facilities within a large-scale city by living areas and basic living areas. The construction stage code distinguishes the characteristics of stages such as design, construction, procurement and commissioning. Using the ANS as shown on Figure 4-7 enables the categorization of hierarchically-arranged WBS down to the subcategory, as well as systematic promulgation of information upward. Also, the ANS allows for systematic and effective tracking of progress status information by: i) living area ii) construction stage iii) key facilities and iv) participants.

4.1.4 Weighing of subordinate facilities to key facilities

For Level 1 facilities within the S-City, weighed value as determine earlier through survey was used. The weighing criteria for Level 2 subordinate facilities are to be applied while reflecting the properties of each subordinate facility. Level structure for key and subordinate facilities was done as per the Work Breakdown Structure. Weighing criteria of subordinate facilities(Level 2) to key facilities is as follows.

(1) Site preparation facilities

Site preparation facilities are comprised of groundwork, landscaping, demolition, artifact excavation, etc. Groundwork and landscaping are based on area(㎡) per basic living areas linked to greater living areas, and previously ordered groundwork and landscaping construction areas are reviewed to calculate weighing criteria. On referring to results for living areas 1-1, 1-2, 1-3, 1-4, where the groundwork and landscaping works are already completed, groundwork area-per-landscaping area ratio is shown at Table 4-3 below.

<Table 4-3> Landscaping surface area as compared to site development surface area

(Unit : ㎡)

Living area	Groundwork Area(A)	Landscaping Area(B)	Combined Area (C=A+B)	Groundwork ratio(A/C)	Landscaping Ratio(B/C)
1-1 living area	5,313,057	2,233,377	7,546,434	70.4 %	29.6 %
1-2 living area	2,244,850	708,195	2,953,045	76.0 %	24.0 %
1-3 living area	1,147,263	142,583	1,289,846	88.9 %	11.1 %
1-4 living area	2,034,087	657,532	2,691,619	75.6 %	24.4 %

As shown at Table 4-3 above, there are differences on groundwork areas landscaping areas for each basic living areas. Thus, groundwork areas and landscaping areas for each basic living areas will be applied to weighing criteria for Site preparation sites on each area. The quantity of previously contracts reflect contract items, and the quantity of not yet contracted ones are reflected referring data from living area 1.

(2) Transportation facilities

A agency and a developer divide the area of responsibility to supervise transportation facility projects. Government-supervised metropolitan roads include Osong station access way, Daeduk techno access way, Jeongan IC access way, and the developer supervise public transport main roads, city outer ring highways, city access way and inner access ways. Public transportation main roads include regional BRT(Bus Rapid Transit) roads, Handoori bridge(Geumgang bridge 2), Aramchan bridge(Geumgang bridge 4), and city outer ring highways include regional detours, Haknarae bridge(Geumgang bridge 1), and Geumbitnoeul bridge(Geumgang bridge 5). City access ways and inner access ways include Osong station access way, Jeongan IC access way, Haetmuri bridge(Geumgang bridge 3), and Haetmuri bridge access ways. The weighing criteria for those roads are defined as completed length of facilities(km) per total length(km) Table 4-4 shows the weighing criteria for subordinate facilities of transportation facilities over length.

<Table 4-4> Weighed value of transportation facilities

Type	Length(km)	Weighed value(%)	Notes
Metropolitan Roads	118.4	66.5	
Public Transportation Main Roads	25.3	14.3	
Inner Access ways	3.6	2.0	
City Outer Ring Highways	30.6	17.2	
Total	177.9	100.0	

(3) Urban utility facilities

Urban utility facilities are crucial facilities to urban life, such as electricity, gas, communications facilities, etc. Developer supervises automatic clean net, water restoration Center, waste disposal facility and landfill, and individual entities supervise electricity, gas, heat supply, telecommunication projects. Several facilities such as water restoration center and waste disposal facilities are installed for relevant basic living area units, and some such as automatic clean net are composed of multi-living area plumbing and collection center. Due to the difficulty in determining a single, unified weighed value for urban utility facilities while reflecting their properties, the weighed value of urban utility facilities is determined based on project costs. Table 4-5 shows weighing criteria for urban utility facilities.

<Table 4-5> Weighed value of urban utility facilities

Type	Project cost (100million KRW)	Weighed value(%)	Notes
Electric Supply facilities	3,141	12.8	
Mass Energy Supply facilities	12,035	49.0	
Gas Supply facilities	657	2.7	
Telecommunication facilities	183	0.7	
Water Restoration Center	3,707	15.1	
Automatic Clean net	3,858	15.7	
Waste Disposal & Landfill	983	4.0	
Total	24,564	100.0	

(4) Public facilities

A government agency, and other government entities, such as Ministry of Government Administration and Home Affairs divides areas of responsibilities on public facilities. Government agency supervises central administrative facilities, national administrative facilities, and local administrative facilities. Other government entities, such as Ministry of Government Administration and Home Affairs, supervise government funded research institutes, such as Korea Research Institute for Human Settlements, Korea Legislation Research institute, and Sejong National Research Complex. Central administrative facilities include phase 1~3 of government complex, Sejong government office 2, administrative support center. National administrative facilities include presidential archives, national Sejong library, court/prosecution office. Local administrative facilities include city hall of Sejong special autonomic city, education office of Sejong special autonomic city, and fire department building. The weighing criteria for public facilities are defined as the total floor area(㎡) of each building comprising the complex, and the result are shown at Table 4-6.

<Table 4-6> Weighed value of public facilities

Type	Total Floor Area (㎡)	Weighed value (%)	Notes
Central Administrative Facilities	780,097	53.3	
National Administrative facilities	249,099	17.0	
Local Administrative Facilities	172,664	11.8	
Government funded Research Institutes	222,988	15.3	
Transit Parking Lots	38,048	2.6	
Total	1,462,895	100.0	

(5) Culture & welfare facilities

Culture & welfare facilities include community complex facility, metropolitan welfare support center, sports complex, arts center, etc. The weighing criteria for culture & welfare facilities are community complexes on each basic living area, and metropolitan welfare center on greater living areas, national archives museum, and National urban construction museum. The weighing criteria for public facilities are defined as the total floor area(㎡) of each facility, and the result are shown at Table 4-7.

<Table 4-7> Weighed value of culture & welfare facilities

Type	Total Floor Area (㎡)	Weighed value (%)	Notes
Community Complex facilities	349,761	49.4	
Metropolitan Welfare Support Center	124,443	17.6	
Sports Complex	145,035	20.5	
Arts Center	14,630	2.1	
Museum Complex	74,000	10.4	
Total	707,869	100.0	

(6) Educational facilities

Education facilities include kindergartens, elementary schools, middle schools, high schools built on each basic living area. Weighing criteria for schools in each basic living area are total floor area(㎡) of each school, and Table 4-8 shows the result.

<Table 4-8> Weighed value of educational facilities

Type	Total Floor Area (㎡)	Weighed value (%)	Notes
Kindergartens	56,053	2.1	
Elementary Schools	756,518	28.9	
Middle Schools	415,149	15.8	
High Schools	425,498	16.3	
Special Schools	28,029	1.1	
Universities	938,605	35.8	
Total	2,619,852	100	

(7) Residential facilities

Table 4-9 shows the example of multi-family housing, the areas are divided into small, medium, large according to their housing site area on basic living areas. On multi-family housing, small are below 60㎡, medium 60~85㎡, large over 85㎡, and application are defined to small 60㎡, medium 72㎡, large 100㎡. Urban lifestyle housings and officetel are excluded from this research because they have no overall plan and the quantity is set according to the circumstances. For single-family housing, average areas of previously completed housings are applied.

<Table 4-9> Weighed value of residential facilities

Type	Living area	Total Floor Area (㎡)	Weighed value (%)	Notes
multi-family housing	1	3,368,237	24.8	
	2	2,484,167	18.3	
	3	1,648,556	12.1	
	4	920,824	6.8	
	5	2,086,320	15.4	
	6	3,060,280	22.6	
	Total	13,568,385	100.0	
single-family housing	1	941,852	29.7	
	2	185,545	5.8	
	3	-	-	
	4	117,448	3.7	
	5	567,591	17.9	
	6	622,002	19.6	
	S	731,546	23.1	
	Total	3,165,983	100	

(8) Commercial and business facilities

Weighing criteria of the facilities are total floor area(㎡). Table 4-10 shows weighing criteria for commercial and business facilities.

<Table 4-10> Weighed value of commercial & business facilities

Type	Living area	Total Floor Area (㎡)	Weighed value (%)	Notes
Commercial and business facilities	1	1,864,852	29.5	
	2	1,700,677	26.9	
	3	971,764	15.4	
	4	357,492	5.7	
	5	468,064	7.4	
	6	924,724	14.6	
	S	31,184	0.5	
	Total	6,318,757	100.0	

(9) Other facilities

Other facilities are comprised according to basic living areas, and it includes medical facilities, religious facilities, funeral facilities, and gas stations, etc. Progress rate for other facilities are calculated according to total floor area(㎡), and the weighing criteria are shown at Table 4-11.

<Table 4-11> Weighed value of other facilities

Type	Total Floor Area (㎡)	Weighed value (%)	Notes
Medical facilities	426,682	36.9	
Religious facilities	230,984	20.0	
Funeral facilities	17,293	1.5	
Gas stations	29,276	2.5	
Parking lots	443,117	38.4	
Sports facilities	7,890	0.7	
Total	1,155,242	100.0	

For previously defined weighing criteria for subordinate facilities, contracted quantities are applied according to contract items, and not contracted quantities are applied according to planned floor area ratio, etc.

Mentioned above are weighing criteria formula for WBS Level 2 facilities. For Level 3 facilities, subordinate facilities for Level 2 facilities, the formula are same.

4.1.5 Weighing of each Contract Units and designation of Control Points

Calculating formula of weighing criteria for each contract unit on key facilities at S-City follows previous 3.3.3 review and the basis Figure 3-10. For most facilities, 5% weighing criteria for order, 10% for design, 85% for construction are applied. For urban utility facilities, procurement and commissioning criteria are added. As a result, it is 5% weighing criteria for order, 10% for design, 25% per procurement, 55% for construction, and 5% for commissioning.

For control points on order, design, construction work phase, it follows previous 3.3.4 large-scale city construction control points. Thus, on order phase, it is 50% for notice of tender, 90% for bidder selection, 100% for conclusion and start of the contract. On design phase, it is 30% for conformation submission, 80% for construction submission, and 100% for final submission. On procurement phase, it is 35% for order, 85% for manufacture and examination, and 100% for transportation and on-site delivery. On construction phase, it will be calculated according to the key quantity of major work items, by applying result for each calculating units. On commissioning phase, it is 30% for pre-check and initiation, 80% for initiation of full commissioning, and 100% for completion of full commissioning.

4.2 Availability review of the Progress Management model for the S-City project

4.2.1 Actual-based determination of progress rate by each area

Progress rate system for S-City can be divided into city, living areas and basic living areas and it is also can be classified into key facilities progress rate for each region(city, living area, basic living area) area.

First, on City-wide progress rate, from late December in 2015, it is 37.4%, and at that time, key facilities progress rate in S-City is as follows in Table 4-12.

<Table 4-12> Progress rate of key facilities(at 37.4% overall progress)

Type	Progress rate (%)	Notes
Site preparation	35.4	
Transportation facilities	58.9	
Urban utility facilities	47.7	
Public facilities	65.8	
Culture & welfare facilities	20.5	
Educational facilities	26.7	
Residential facilities	22.4	
Commercial facilities	17.9	
Other facilities	5.3	

As Table 4-12 above shows, the progress rate for key facilities in city-wide 37.4% progress rare point is as follows. The progress rate are 35.4% for site preparation, 58.9% for transportation, 47.7% for urban utility, 65.8% for Public, 20.5% for cultural & welfare, 26.7% for education, 22.4% for residential, 17.9% for commercial & business, and 5.3% for other facilities. At this point, public facilities are the most finished one, and transportation, urban utility, site preparation follows. Other facilities above are comprised of religious, parking, medical facilities, and gas station.

On city-wide progress rate for S-City, there are plan for 22.5 trillion KRW on public facilities, there are not timeline-based plans for private sectors, and only population for each phase(300 thousands by 2020, 500 thousands by 2030) can be referred. So, it is currently limited to give city-wide progress rate a detailed meaning now. There are also a need for a separate research on population-based phased urban planning.

The S-City is comprised of 6 living areas, and each area are planned to have their unique characteristics. Living area 1 is central administrative area, and living area 2 is for cultural and international exchange area. Living area 3 is for local city administration facilities, Area 4 is for college and research facilities, area 5 is for medical & welfare, and area 6 is for technology & knowledge base facilities.

There are currently phased urban planning in progress, and the area of living area and basic living area, population are shown at Table 4-13.

<Table 4-13> Breakdown of living areas in S-City

Stage	Living area	Basic Living Area	Area(㎡)	Population (persons)
1	1	1-1	1,679,551	37,490
		1-2	806,994	24,061
		1-3	676,771	27,820
		1-4	825,599	25,582
		1-5	373,782	20,000
	2	2-1	867,804	30,920
		2-2	708,661	27,398
		2-3	641,288	17,500
		2-4	289,039	13,220
	3	3-1	435,320	18,268
		3-2	498,834	19,117
		3-3	806,391	29,978
2	4	4-1	508,497	19,755
		4-2	836,165	29,575
	5	5-1	819,521	23,047
	6	6-1	701,845	19,139
		6-2	837,051	30,801
		6-4	561,755	15,477
	S	S 1,2	941,609	7,578
3	5	5-2	562,137	16,298
		5-3	645,697	19,268
	6	6-3	773,129	27,708

On Table 4-13, living area 1-1 is the largest, and the most populous one. And area 2-1, and 6-2 follows. On the table above, a large-scale city is forming in time and space.

By late December of 2015, when the city-wide progress rage is 37.4%, the progress rate for each living areas are shown at Table 4-14.

<Table 4-14> Progress rate of living areas(at 37.4% overall progress)

Living area	1	2	3	4	5	6	S	Misc.	Notes
Progress rate(%)	73.6	29.5	29.9	10.2	0.0	1.0	44.4	58.2	

As shown at Table 4-14, by late December of 2015, living area 1 are most formed one, and miscellaneous area, S-living areas, living area 3, and living area 2 follows. Other areas mainly comprise of S-City and metropolitan road constructions, and S-living areas are affected by central park, etc.

Next is progress rate of basic living areas. On each living area, resident, for example, in living area 1, are in 1-1 to 1-4 living areas, and in living area 2-3, which are completed at November 2011. On five basic living areas stated, the Chutmaeul, living area 2-3, it is hard to collect date as it is a separate LH project. For 4 remaining basic living areas, Table 4-15 shows the timeline-based progress status on key facilities.

<Table 4-15> Progress rate of living areas

Type	1-1 living area			1-2 living area			1-3 living area			1-4 living area		
	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
Site preparation	71.3	93.2	100	62.9	80.6	93.5	75.4	90.2	96.5	69.7	91.0	100
Transportation	-	-	-	-	-	-	-	-	-	-	-	-
City Supply	71.3	93.2	100	62.9	80.6	93.5	75.4	90.2	96.5	69.7	91.0	95.5
Public	-	-	-	1.5	11.5	41.3	-	-	-	-	-	-
Culture & welfare	10.0	13.4	32.7	49.6	92.6	100	21.0	43.5	85.4	74.1	100	100
Educational	7.3	58.0	100	23.1	49.8	87.8	0.0	14.9	51.4	8.9	36.9	100
Residence	15.9	52.2	73.8	13.7	45.7	81.6	29.8	61.9	79.0	30.0	77.4	96.3
Commercial	0.0	21.6	54.3	0.0	18.1	40.6	0.0	21.0	42.0	0.0	33.0	100
Other facilities	3.2	9.1	20.7	0.0	0.0	19.0	0.0	29.0	57.2	0.0	0.0	0.0

As shown on Table 4-15 above, on each basic living area, formation of several key facilities shows some form of consistency, but some do not. Transportation doesn't show up as those are metropolitan roads, so not included in basic living areas. For Urban utility and disposal facilities, as it tends to be built simultaneously with site preparation, progress rate of site preparation is applied to.

4.2.2 Proposition of progress rate using a simulation

Based on the performance values Table 4-15 above, the criteria for the timeline-based progress rate on the key facility components will be presented. The methods available would be mean- and regression analysis-based calculations, but to run those methods, one would need sufficient number of samples to get a fair result, or it would be hard to get reliable values.

Thus, on this research, probabilistic analysis would be used to calculate criteria for the timeline-based progress rate on the key facility components. Unlike definite analysis, which presents singular value on the object, probabilistic analysis uses statistical analysis technique, reflecting uncertainties of input values, by applying random sampling simulation on probability distribution values of input values, using commercial software packages, to calculate the degree of uncertainty as output values.

(1) Simulation

Normally, a simulation is a computerized recreation of present or future situations with mathematical and logical models to understand a system and help decision-making. In other words, it is a tool to design a system so it would be possible to predict a system or conserve time and cost, by establishing a miniaturized physical, mathematical model or a sketch of a system and testing it under various environments. Even if it has to be understood that the result of a simulation is an approximate value, simulation has several edges over other analytical methods.

- Able to foster more accurate judgment by decision-makers through a set up assumptions on the distribution that many components may have
- Considers relationships between components
- Can decide on the distribution based on model development
- Can improve accuracy by repetition
- Can shorten model development time
- Can analyze model behavior more easily

(2) Monte Carlo Simulation

The Monte Carlo simulation technique, a technique that make random numbers based on probability distribution function to make a random sample, and tweak the mathematical expectation with repeated extraction test, will be applied to this research.

Monte Carlo simulation is used to help decision-making process when facing an uncertain situation, and it widens the range of possible information to decision-makers by giving them more variety of choices other than simple result based on expectations. The core of the Monte Carlo simulation is the experiment on the probability of the model components, using tools which creates a probable or coincidental results. This tool creates coincidental results, using random sampling according to the model-assumed probability distribution. Thus, Monte Carlo simulation is also called simulated sampling technique. By setting probability distribution on variables, and using random numbers calculated from the distribution to get the result, the resulting values are same as the ones calculated with actual numbers.

The result derived from Monte Carlo simulation using convergent repetition time can be a realistic data for decision-making, and the values can be set by the optimistic or pessimistic tendency of the decision-maker.

The first procedure for Monte Carlo simulation is, as you can see on the Figure 4-8, establishing decision-making model and understanding the distribution of probability variables. Second part is materializing hypothesis on probable situations, by composing distribution based on past data or subjective judgment of the researcher. The final part is running simulation repeatedly to let the model value converge itself, and get the reasonable value. As a result, the value can be calculated, and analyze sensitivity analysis on variables, to be used on the decision-making process.

Understanding the distribution of the probability variables

↓

Composing cumulative probability distribution

↓

Set random number section

↓

Simulation

↓

Calculation(average, variance, etc.)

↓

Decision-making

<Figure 4-8> Monte Carlo simulation procedure

When the past experiences are useful when applying probable analysis technique, the right probability distribution can be add through goodness if-fit test, which represents how the values are fit to be applied to the theoretical probability distribution. If not, right probability distribution function can be chosen by reflecting expert opinions to get objective value, usually using minimum value, average value, maximum value, etc.

On this research, to present standard progress rate of the key facilities according to the basic living area, Monte Carlo simulation will be used, with Crystal-ball program, developed specifically for Monte Carlo simulation by Oracle.

By referring to the time-based record based on basic living area described in Table 4-15, and present standard progress rate on key facilities, data on Table 4-15 is transformed into the data on the Table 4-16.

<Table 4-16> Progress rate of key facilities based on basic living area progress rate

Progress rate	25%				50%				75%			
Living area	1-1	1-2	1-3	1-4	1-1	1-2	1-3	1-4	1-1	1-2	1-3	1-4
Site preparation	71.3	62.9	75.4	69.7	93.2	80.6	90.2	91.0	100	93.5	96.5	100
Transportation	-	-	-	-	-	-	-	-	-	-	-	-
Urban utility	71.3	62.9	75.4	69.7	93.2	80.6	90.2	91.0	100	93.5	96.5	100
Public	-	1.5	-	-	-	11.5	-	-	-	41.3	-	-
Culture & welfare	10.0	49.6	21.0	74.1	13.4	92.6	43.5	100	32.7	100	85.4	100
Educational	7.3	23.1	0.0	8.9	58.0	49.8	14.9	36.9	100	87.8	51.4	100
Residence	15.9	13.7	29.8	30.0	52.2	45.7	61.9	77.4	73.8	81.6	79.0	96.3
Commercial	0.0	0.0	0.0	0.0	21.6	18.1	21.0	33.0	54.3	40.6	42.0	100
Other facilities	3.2	0.0	0.0	0.0	9.1	0.0	29.0	0.0	20.7	19.0	57.2	0.0

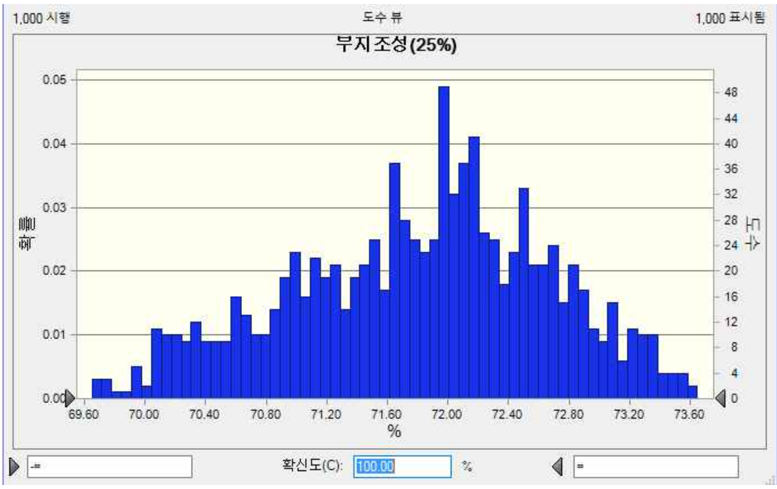
As one can see on Table 4-16 above, according to record data on large-scale city, progress rate on basic living areas are broke up into 25% point, 50% point, and 75% point. On site construction at 25% basic living area progress rate, 1-1 living area shows 71.3%, 1-2 living area shows 62.9%, 1-3 living area shows 75.4%, 1-4 living area shows 69.7%, and a Monte Carlo simulation will be executed based on those data to present standard value for Site construction progress rate for basic living areas at 25% point.

As stated on Table 4-16 above, transportation facilities means metropolitan roads, which have no value on basic living areas, but it shows 58.9% on Table 4-12, which shows full progress rate on large-scale city. It means that transportation facilities are common of all living areas and they are not included in basic living areas.

Urban utility facilities are set same to site construction rate, as those systems have tendency to be constructed alongside site construction. For public facilities, almost every ones on large-scale city are finished on 1-5 basic living area, and some are currently being constructed on 1-2 living area. For culture & welfare facilities had problems with planning and order on 1-1 basic living area and caused discomfort among residents, there are currently several early plans for culture & welfare facilities at other basic living areas. Thus, for 1-1 basic living area, as it has several features including reschedule request from the local government, the principal managing entity, as well as resulting delays, it has been excluded from the simulation input data package. Educational facilities have similar features, for example, on 1-3 basic living area, school design and order has been concentrated on 2014 due to past delays. In other basic living areas, the progress has been going normal, considering what happened in area 1-3. Thus, data from 1-3 basic living areas has been excluded from the simulation input data package. For residential facilities, comprised of multi-family housing and single-family housing, on large-scale city, currently most of the multi-family housing are already purchased, but considering the nature of single-family housing, which need to get its sited purchased first to get it built, and smaller supply, only data on multi-family housing are included.

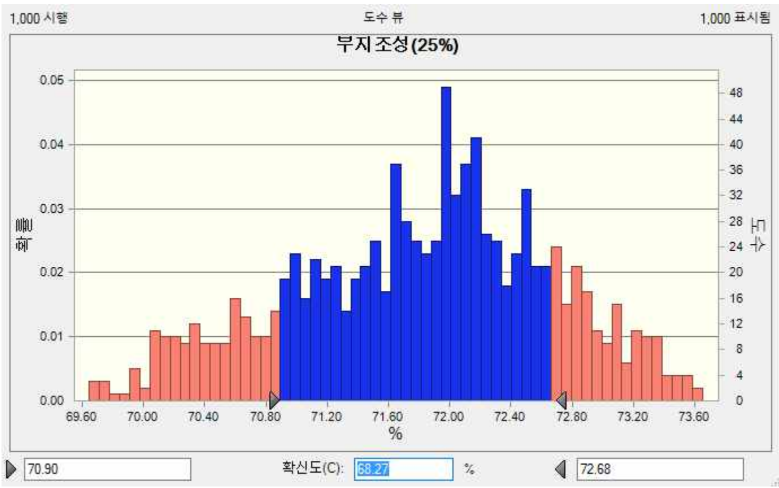
From previous basic living area progress rate 50% and 75% from the Table 4-16, culture & welfare facilities at 1-1 living area, educational facilities at area 1-3, and miscellaneous facilities at area 1-4 have also been excluded due to distinct characteristics of each basic living area.

Using the Crystal-ball, a Monte Carlo simulation has been executed to calculate values converged for progress rate of each key facility on 25%, 50%, 75% point, for each basic living area. For probability distribution of key facilities on 25% point progress rate at basic living areas, triangulated distribution is used for most facilities, and uniform distribution is used for public facilities and miscellaneous facilities. For 50% and 75%, uniform distribution has been used only for public facilities, and triangulated distribution has been used for the rests. The simulation has been executed 1,000 times, and the example of site construction at 25% basic living area is on the Figure 4-9.



<Figure 4-9> Site preparation progress, assuming 25% basic living area progress rate

On the picture above, the entire range of site construction is between 69.65~73.65, average value is 71.81, standard deviation is 0.85, skewness is -0.2567 and kurtosis is 2.44. Range of 68.27%, section of μ±1 is 70.90~72.68, as shown at Figure 4-10



<Figure 4-10> μ±1σ section(within 68.27% range)

The result of executed simulation on each key facilities for 25%, 50, 75% basic living area progress rate is shown at Table 4-17 below.

<Table 4-17> Simulation results by key facilities

Type	25%		50%		75%	
	Scope	Ave-rage	Scope	Ave-rage	Scope	Ave-rage
Site preparation	69.65～73.65	71.81	88.30～92.30	90.60	97.30～99.40	98.50
Urban utility	69.74～73.70	71.85	88.30～92.30	90.70	97.30～99.40	98.50
Public facilities	1.35～1.65	1.50	10.35～12.65	11.47	37.18～45.42	41.30
Culture & welfare facilities	48.30～65.50	57.40	78.90～97.40	90.60	92.70～97.50	95.20
Educational facilities	13.18～18.17	15.04	48.40～55.10	52.20	94.00～97.90	95.90
Residential facilities	25.30～29.90	28.30	64.10～72.00	67.70	85.70～91.20	87.70
Commercial	-	-	25.30～29.10	26.60	63.80～84.40	73.20
Other facilities	2.88～3.52	3.19	19.10～25.60	22.40	32.40～44.50	36.80

With data from 25% progress rate on basic living areas, the result of comparison with data from basic living area 3-2 and 3-3, where some of residents started moving in, and basic living area 2-2, where move-in will commence in 2017, are at Table 4-18.

<Table 4-18> Progress rate of key facilities(at 25% basic living area progress)

Type	Progress rate(%)			Notes
	3-2 living area	3-3 living area	2-2 living area	
Site preparation	71.4	74.4	68.2	
Urban utility facilities	71.4	74.4	68.2	
Public facilities	41.6	-	-	
Culture & welfare facilities	12.2	8.0	21.9	
Educational facilities	5.2	28.5	26.3	
Residential facilities	13.6	34.8	23.9	
Commercial facilities	19.7	2.0	0.7	
Other facilities	-	-	2.8	

When compared to data from basic living area 3-2, which were analyzed using previous end results, there are tendency to show high progress rate for public facilities due to preferential supply of city administrative facilities such as city hall and Department of Education, but low progress rate for cultural & welfare, education, and residential facilities. In this case, even though it cannot be said that progress rate of residential facilities falls behind the progress rate based on previous result-based ones, as it can cause residents not able to use cultural & welfare facilities and educational facilities when they move in, the investment time frame should be readjusted.

For basic living area 3-3, progress rate for site construction, residential facilities, and educational facilities are going normal, but it also shows markedly slow rate for cultural & welfare facilities. Also, for basic living area 2-2, where residents will start moving in from the first half of 2017, when compared to Table 4-17, progress rate for key facilities are keeping up in principle, it need readjustment due to low progress rate for cultural & welfare facilities. Thus, as cultural & welfare facilities for residents are not ready, residents may use facilities from other living areas, and cause inconveniences when the construction for those facilities are still ongoing even after move-in.

It is possible to examine and analyze ongoing progress rate on major facilities at basic living areas, using table 4-17 as the standard, and use the analysis to apply it to the city-building process, such as adjusting investment time frame for each facility, or allocating funds.

The above data itself, using 4 basic living areas, is not yet credible enough to use it as a standard, but after some time, more data from other basic living areas can be used to improve the credibility of the data. S-City has 21 basic living areas total, and if the data processed above can be used, it would be possible to use the resulting data for other multiple basic living areas, and support efficient decision-making process for the composition of a city based on basic living areas.

4.3 Verification of Progress Management model through survey

To verify the progress management model for large-scale city construction projects this research proposed, and explore expected possibilities, several expert interviews have been conducted. The interviewees are 23 experts on city-building process.

The purposes of the interview are as follows.

First, to examine its efficiency and validity of the progress management model for large-scale city construction projects this research proposed.

Second, to examine its usefulness on field and applicability to other projects for large-scale city construction projects this research proposed.

Finally, to examine its originality for the progress management model for large-scale city construction projects this research proposed

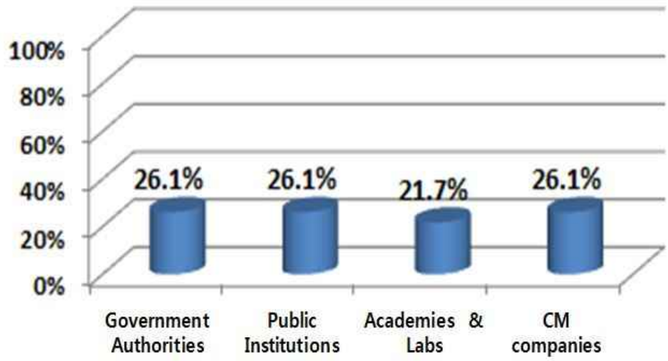
4.3.1 Survey overview

The survey process started with explanation of the deduction, and exact methodology for the progress management model for large-scale city construction projects this research proposed, and review on 5 articles. The summary of the survey are on Table 4-19.

<Table 4-19> Survey overview

Type	Details
Purpose	Verification of Progress Management model for large-scale city construction projects
Date	2016.8.22 ~ 2016.9.13
Subject	Experts and action-level personnel in government agencies, public institutions, academic and research institutions, Project Management firms, etc.
Method	Physical and E-mail interview
Number	23 persons

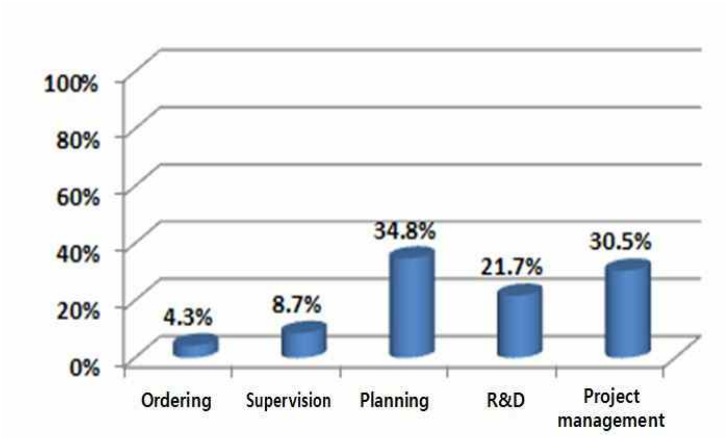
Affiliation Distribution of the interviewees are on Figure 4-11.



<Figure 4-11> Breakdown of survey respondents by organization

On Figure 4-11, the affiliations of interviewees are 26.1% from Government Authorities(6), 26.1% from Public Institutions(6), 21.7% from Academies & Labs(5), and CM companies(6).

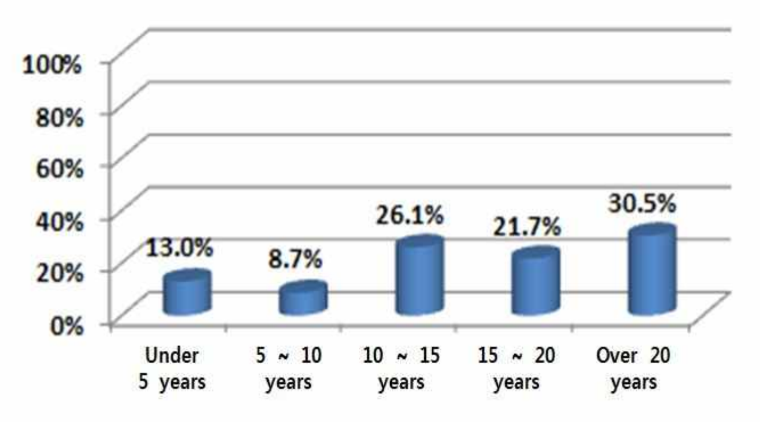
On Figure 4-12, the Area of Responsibilities for interviewees are divided into order, supervision, planning, R&D, and project management



<Figure 4-12> Breakdown of survey respondents by role

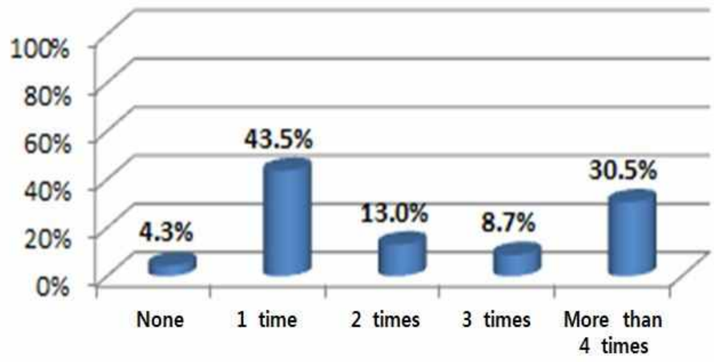
There are 4.3% from order(1), 8.7%(2) from supervision, 34.8%(8) from planning, the largest group, and 21.7%(5) from R&D. There are 30.5%(7) from project management, mostly from government urban planning, public construction administration & planning, and project management areas.

Figure 4-13 below is a breakdown of survey respondents by experience.



<Figure 4-13> Breakdown of survey respondents by experience

On Figure 4-13 below, 30.5%(7) of the respondents had an experience of 20 years and above, followed by 15 years and above (21.7%, 5), 10~15 years(26.1%, 6). About 78.3%(18) of the respondents had more than 10 years of experience.



<Figure 4-14> Breakdown of survey respondents by experience in large-scale city construction projects

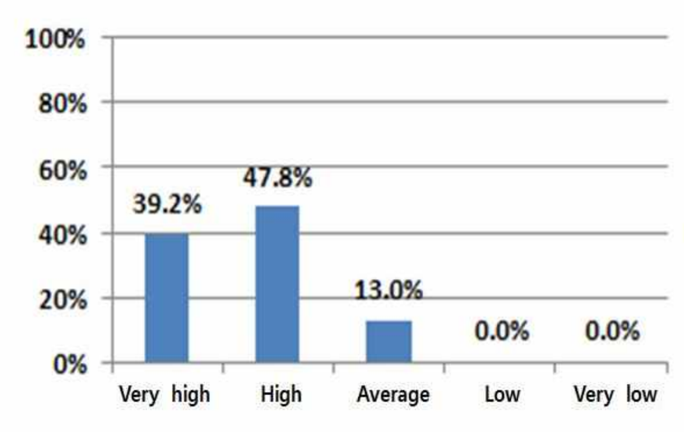
Figure 4-14 is for experiences in major urban planning, and over 95.7% of the interviewees have at least 1 experiences.

4.3.2 Survey result

The survey result for the progress management model for large-scale city construction projects this research proposed is as follows.

(1) Validity

For the validity review, result is shown at Figure 4-15.

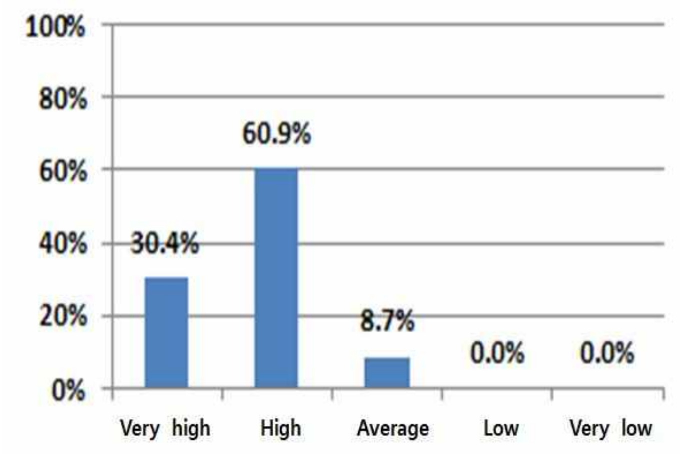


<Figure 4-15> Validity verification result

87% of the experts(20) deemed it highly valid. There were multiple expert opinions stating it had high validity on managing actual progress management for large-scale city construction projects.

(2) Efficiency

For the efficiency review, result is shown at Figure 4-16.

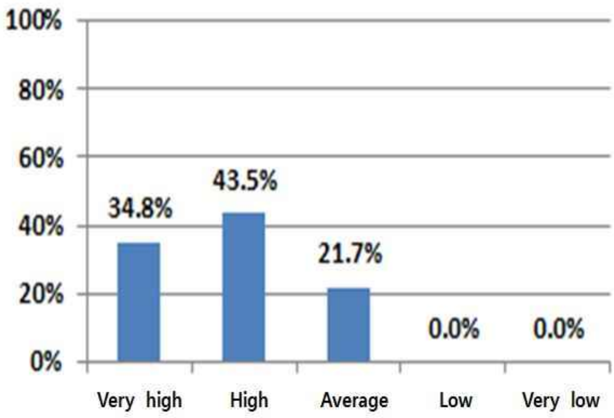


<Figure 4-16> Efficiency verification result

91.3% of the experts deemed it highly efficient. It would be safe to say that most of the experts deemed it efficient to objectively calculate progress rate, including both public- and private-sector.

(3) Real-world utility

For the real-world utility review, result is shown at Figure 4-17.

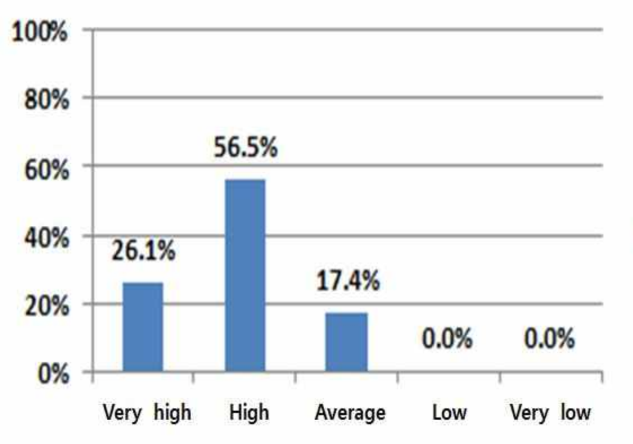


<Figure 4-17> Real-world utility verification result

78.3% of the experts deemed it highly useful. It would be safe to say that most of the experts deemed it useful to use the result on large-scale city construction projects.

(4) Applicability

For the applicability review, result is shown at Figure 4-18.

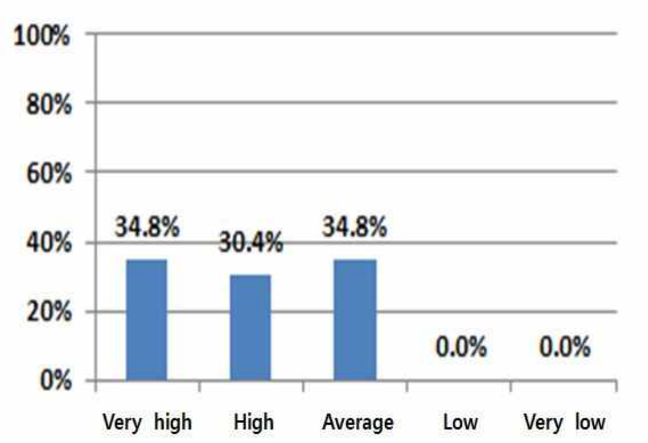


<Figure 4-18> Applicability verification result

82.6% of the experts deemed it highly applicable to other similar projects. Especially, there were calls to establish regional information regarding the characteristics of large-scale city, this research used regional Breakdown method.

(5) Originality

For the originality review, result is shown at Figure 4-19.



<Figure 4-19> Originality verification result

65.2% of the experts deemed it original, and there were comments that it is a creative study on combined management, considering the complexity of specialization among various project entities and facilities.

4.3.3 Survey result review

Experts deemed highly in the criteria, and there was mutual sympathy that this research presented new progress management model on large-scale city construction projects. But, if there are further adjustments on real-world utility regarding weighed grades basis, it could be more positively used in real-world projects. And as control points weighed grades were applied to major national projects such as railroad, airport, and nuclear plants, it would have a lot of significance if obtain more domestic and international large-scale city construction projects data to upgrade its objectivity.

4.4 Information system development for Progress Management of the S-city project

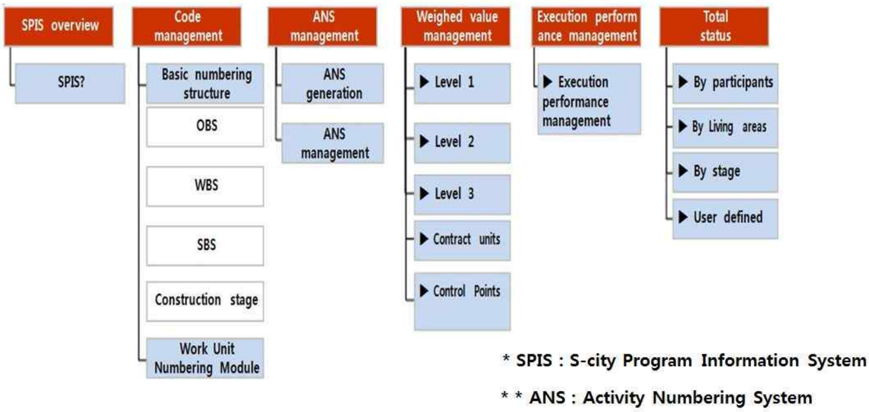
4.4.1 System design

This system models abstract objects of components for progress management information system, to realistic depiction of key facilities on S-City, a massive and complex city.

On system development server, among WAS(Web Application Server), which provide web server-synced Java environment, such as Apache Tomcat, Jeus, Jetty, Web Logic, the Apache Tomcat, which has similar function and is open-sources, has been used. On development program language, among JSP(Java Server Page), PHP(Personal Home Page tools), ASP(Application Service Provider), JSP has been selected. It has favorable inter-system transplant tendency, favorable server resource usage, fast response speed, and easy programming by providing multiple script elements, such as expression language, expression formula and action tags. It also provides easy cooperation environment thanks to easiness of source analysis, and no platform restriction thanks to Java language, and excellent linkage with other frameworks.

4.4.2 System composition overview

Information system for S-City planning progress rate is composed of project entities, Work Breakdown structure, Section Breakdown Structure, code management modules for registering and managing construction phases, and derived activity numbering system & management modules, and level-based weighed value management module for each facilities, periodic actual management module and summary information management module, etc. Software composition of the system is shown at Figure 4-20.



<Figure 4-20> Software architecture of the information system for Progress Management of the S-City

(1) Code Management Module

Code management module is a codified module for summarizing and totaling the progress rate for major S-City project. The module is comprised of basic numbering system, and activity numbering system. The basic numbering system is comprised of Organization Breakdown System, Work Breakdown System, Section Breakdown System, and construction phases. The detailed system screens are as follows.

1) Basic Numbering System

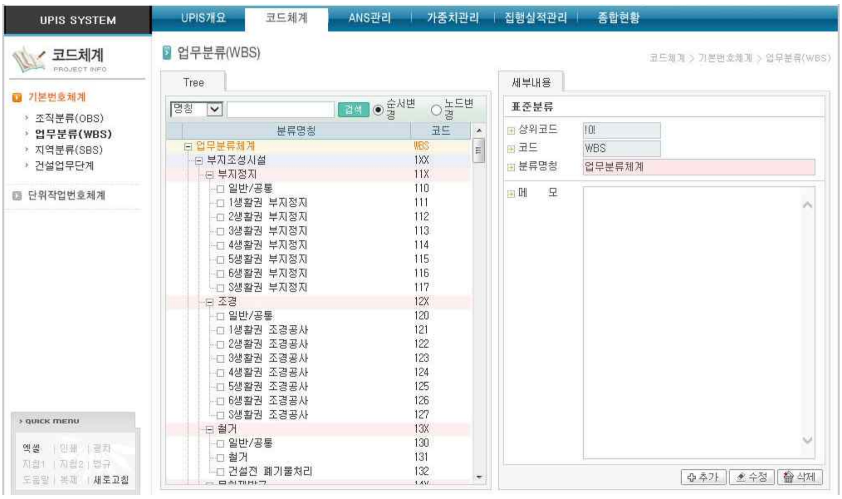
▪ Organization Breakdown Structure(OBS)

This is a numbering system based on the operating organization of the large-scale city construction projects, and forms the basis of project entities based progress rate calculation. Figure 4-12 shows the OBS system screen.

<Figure 4-21> Code structure – Organization Breakdown Structure(OBS)

- Work Breakdown Structure(WBS)

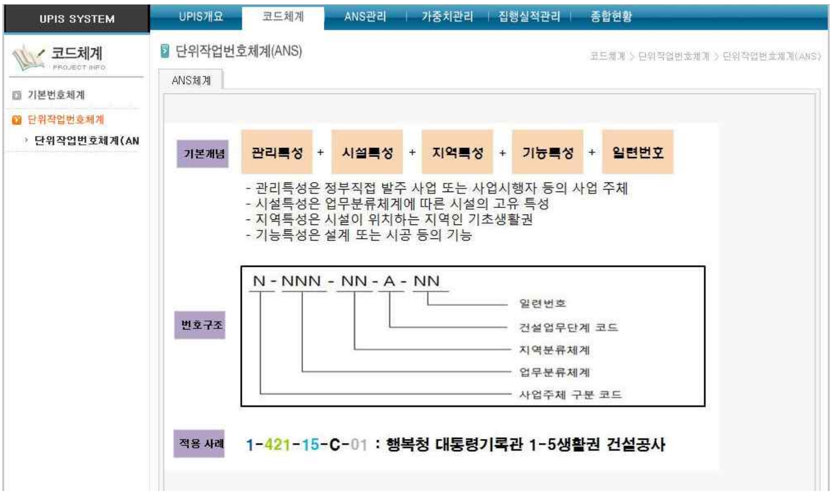
Work Breakdown Structure, developed at Chapter 3, has been stratified, and linked to parent entities. Figure 4-22 shows the WBS system screen.



<Figure 4-22> Code structure – Work Breakdown Structure(WBS)

2) Activity Numbering System(ANS)

The basic concept, numbering structure, and examples of activity can be found at ANS module



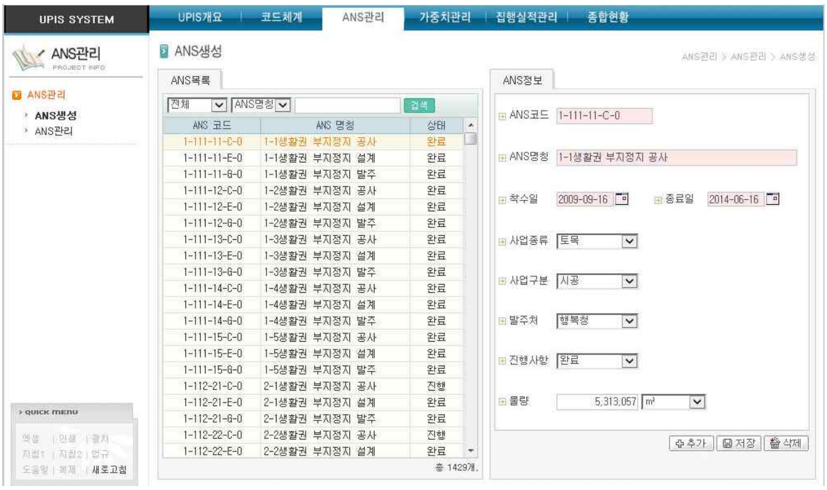
<Figure 4-23> Activity Numbering Structure

(2) ANS management module

ANS management modules are comprised of ANS creation and ANS management

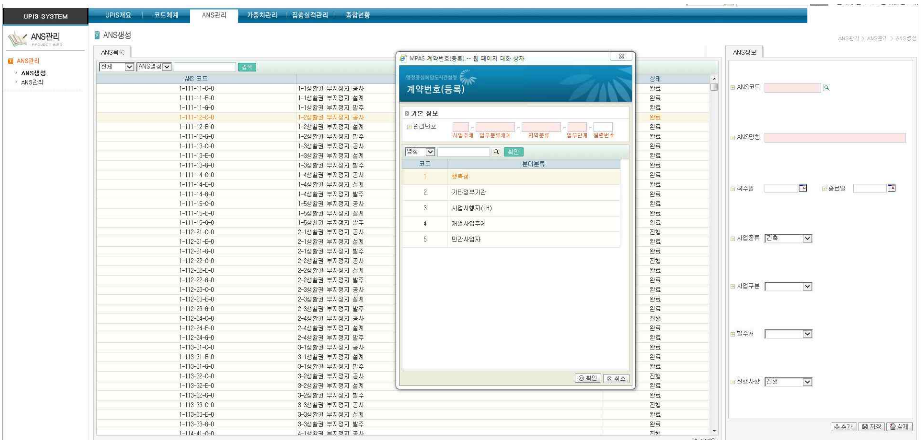
1) ANS Creation

ANS creation module can be modified when there are new work units, change of quantity in work unit, or change of schedule. Quantity information changed in ANS Creation screen are reflected to the weighed value management. Figure 4-24 is ANS information screen.



<Figure 4-24> ANS management – ANS details

Figure 4-25 shows ANS creation screen with selecting project entities, WBS, RBS, Work level through pop-up screen.



<Figure 4-25> ANS management – ANS code generation

2) ANS Management

Overall ANS status, start date, end date, progress can be found at ANS Management module. Newly created ANS from ANS creation modules, and changed weighed value due to change of quantity are automatically reflected. Figure 4-26 is ANS management screen.

ANS 코드	ANS 명칭	착수일	종료일	물량 데이터	단위	가중치	상태
1-111-11-C-0	1-1생활권 부지정지 공사	2009-09-16	2014-06-16	5,313,057	㎡	0.61595	완료
1-111-11-E-0	1-1생활권 부지정지 설계	2008-05-01	2008-09-30	0	㎡	0.07246	완료
1-111-11-G-0	1-1생활권 부지정지 발주	2009-08-01	2009-09-09	0	㎡	0.03623	완료
1-111-12-C-0	1-2생활권 부지정지 공사	2008-04-07	2014-05-31	2,244,850	㎡	0.26025	완료
1-111-12-E-0	1-2생활권 부지정지 설계	2007-08-01	2007-12-31	0	㎡	0.03062	완료
1-111-12-G-0	1-2생활권 부지정지 발주	2008-01-01	2008-02-29	0	㎡	0.01531	완료
1-111-13-C-0	1-3생활권 부지정지 공사	2009-09-16	2013-12-15	1,147,263	㎡	0.13300	완료
1-111-13-E-0	1-3생활권 부지정지 설계	2008-05-01	2008-09-30	0	㎡	0.01565	완료
1-111-13-G-0	1-3생활권 부지정지 발주	2009-08-01	2009-09-09	0	㎡	0.00782	완료
1-111-14-C-0	1-4생활권 부지정지 공사	2007-12-10	2014-08-31	2,034,087	㎡	0.23582	완료
1-111-14-E-0	1-4생활권 부지정지 설계	2007-04-01	2007-08-31	0	㎡	0.02774	완료
1-111-14-G-0	1-4생활권 부지정지 발주	2007-09-01	2007-12-06	0	㎡	0.01387	완료
1-111-15-C-0	1-5생활권 부지정지 공사	2007-06-18	2014-04-30	2,487,535	㎡	0.28838	완료
1-111-15-E-0	1-5생활권 부지정지 설계	2007-01-31	2007-03-31	0	㎡	0.03393	완료
1-111-15-G-0	1-5생활권 부지정지 발주	2007-04-01	2007-07-01	0	㎡	0.01696	완료
1-112-21-C-0	2-1생활권 부지정지 공사	2012-11-26	2015-11-25	1,704,915	㎡	0.19765	진행
1-112-21-E-0	2-1생활권 부지정지 설계	2011-07-01	2012-07-30	0	㎡	0.02325	완료
1-112-21-G-0	2-1생활권 부지정지 발주	2012-11-16	2012-11-16	0	㎡	0.01163	완료
1-112-22-C-0	2-2생활권 부지정지 공사	2012-11-26	2015-11-25	1,492,368	㎡	0.17301	진행
1-112-22-E-0	2-2생활권 부지정지 설계	2011-07-01	2012-07-30	0	㎡	0.02035	완료

<Figure 4-26> ANS management – ANS list

(3) Weighed Value Management Module

1) Level 1

Level 1 facility weighed value is on 9 key facilities, based on survey and AHP, and quantity on each facility can be changed, but the weighed value itself doesn't change. Figure 4-27 is Level 1 weighed value management screen.

<Figure 4-27> Weighing management module – Level 1

2) Level 2

Level 2 is weighed value on lower-level facilities of Level 1 facilities, and the weighed value changes with quantity. Quantity change of Level 2 follows quantity change from ANS creation module. Figure 4-28 is level 2 weighed value management screen.

<Figure 4-28> Weighing management module – Level 2

(4) Actual Management Module

Actual management module calculates contract-based execution result for each unit facility, and it can be divided into basic plan, actual plan, result, and date. Basic plans are fed according control points weighed value, and actual plan can be changed according to the characteristics of unit facilities. Result are fed monthly, referring to the weighed value of actual plan. Figure 4-29 shows the execution result management module system screen.

<Figure 4-29> Budget execution management module

(5) Summary Information Management Module

It presents, such as change of quantity in unit facilities, or plan-to-actual result status, can be found by project entities, Living Area-, Work Phase-specifics base on summary information management module.

1) Overall Project Status

Public and private Sector project status, and combine status can be found at Overall Project Status. Figure 4-30 shows the overall project status system screen.

<Figure 4-30> Overall status – overall progress

2) Project Entity Status

Plan-to-actual status, divided by entities, such as construction agency, developer, and other government entities can be found here. Search function also enables one to view monthly status. Figure 4-31 shows the project entity status system screen.

<Figure 4-31> Overall status – progress by project participants

Chapter 5. Conclusion

This study, through its focus on the S-City project, a large-scale city construction project currently underway under the lead of Korea government as part of its policy of relocating government functions away from the capital region and fostering balanced national growth, has proposed a method for progress management for large-scale city construction projects. Common methods used for progress measurement of previous construction projects use the project cost and progress rates derived from the budget. In large-scale city construction projects, multiple entities, along with the project operator or ordering entity, participate in the project, and both private and public investments are involved. Thus, legacy methods of progress management are limited in its ability to realistically express project progress. Especially, large-scale city construction projects that last for a long time have a large variation between the level of costs incurred and actual realization of the project plan. Only the public sector investment is included in the executed budget and initial costs such as land compensation are also counted. Thus, the actual construction progress tends to appear to be far less than what the "executed budget" would suggest. Also, in most city construction projects, only the public section of the project, funded by government funds, are managed while forgoing the management of the private section, such as urban utility facilities, educational facilities, residential facilities, commercial facilities, etc. Therefore, legacy methods of progress management can only provide an understanding of the money spent on certain sections within a specific time period, and cannot be used as a systemic, step-by-step progress management tool for city construction management that provides milestones such as sections that needs funding, future funding timeline, land provision timeline, optimal lease timeline, etc. For long-term city construction projects, from the project's start to finish, planned schedule and actual timeline must be compared, and in case of any delays, mitigation plans must be made and step-by-step measures must be planned and executed in order to ensure more smooth execution of the project. Legacy methods only measure the progress in terms of cost and budget, and are limited in its accuracy in expressing the status of the construction project, due to the fact that cost allocation in construction projects tends to concentrate significant part of its cost in the beginning. Thus, it is difficult to use the data from such methods to formulate and apply project plan. Under legacy methods, duration and weight of each activities are not considered at all, and it is impossible to understand the connection and relationship between different endeavors. While the ordering entity may be able to obtain an understanding of how much money is spent, such understanding is limited in its usefulness towards determining a meaningful direction for the project. For city construction projects, a set of standards for effectively managing and controlling multiple participants is critical. Therefore, it is important to weigh each activities by importance, timeline, and potential effect on follow-up stages, instead of simply using the amount of money spent to perform progress management.

Therefore, this study began with a case study of actual city construction projects, followed by a literature review of studies pertinent to progress management. Also, a series of breakdown and numbering structures such as the WBS, SBS, and ANS were developed to serve as basic information for progress management of city construction projects. The data was arranged in a hierarchical structure in order to determine weighed values for key facilities. A survey of city construction and construction project management experts was conducted using the AHP method. As for the determination of weighed values for contract units of key facilities, positive feedback was obtained through expert interviews.

At the lower level, the concept of Control Points, used in nuclear power plant construction projects in Korea, as well as key construction projects overseas, was applied in order to measure the objective progress rate for each task.

In order to review the utility of the proposed progress management model, a Monte Carlo simulation was conducted based on the progress of key facilities in the completed parts of the basic living area. Using the projected progress rate, the progress of key facilities in the parts of the basic living area that are still under construction were compared, enabling decision support for prioritizing investment to different facilities.

Also, an information system tailored for progress management of the S-City project was developed. This information system enables users to access information such as overall progress, progress by project developer and region, and status of tasks such as order placement, design, and construction, as well as information tailored for the individual user with ease.

The limited amount of previous research on progress management of large-scale city construction projects proved to be a roadblock for this study. It is hoped that this study will serve as a useful reference for progress management of large-scale city construction projects.

This study, as the only one of its kind that deals with progress management of large-scale city construction projects, has sufficient potential to be used as a standard reference for large-scale city construction projects both in Korea and overseas.

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초 록

최근 세계 각국에서는 국가 기술 산업의 개발과 성장, 수도권 과밀해소 및 인구 분산, 상업 및 주거와 레저의 복합구성, 환경 친화적 기반구축, 행정도시 이전 등을 목표로 대규모 도시를 건설 중이거나 완료 또는 계획 중에 있다.

국내의 경우 국가 균형발전과 경쟁력 강화를 위하여 수도권에 집중되어 있는 정부기능의 분산 정책으로 중부지역에 행정중심복합도시인 S도시가 건설 중에 있다. S-도시 건설사업은 총사업비 내의 공공부문 사업과 총사업비 외의 민간부문 사업으로 구성되어 있으며, 공공이 주도하고 민간이 후속적으로 투자하는 민·관 협업 형태를 나타내고 있다. 정부가 부담하는 공공부문은 S-도시 건설사업을 주관하는 정부기관과 사업시행자가 주관하는 사업으로 부지조성, 교통시설, 공공시설, 문화복지시설 등이며, 민간부문은 다양한 사업자가 참여하는 도시공급 및 처리시설, 교육시설, 주거시설, 상업시설 등이다.

S-도시 건설사업과 같이 다수의 기관 및 사업자가 참여하는 복합적인 대규모 도시건설에 대한 진행 사항을 정확하게 파악하기 위해서는 공공부문 뿐만 아니라 민간부문을 포함한 전체 도시 시설물에 대한 합리적인 진도율 측정 기준과 진도율 산정 방법이 필요하다. 대규모 건설사업이 진행되는 상황을 측정하는 일반적인 방법으로 총사업비 집행율 방식과 사업비를 기준한 공정 진도율 방식이 사용되고 있으나, S-도시 건설사업에 이 방법들을 적용할 경우 S-도시 건설을 주관하는 정부기관과 사업시행자의 공공사업만을 대상으로 포함하고 도시공급 및 처리시설, 교육시설, 주거시설, 상업시설 등이 제외되어, S-도시 건설사업의 전반적인 도시 구성 완성 정도를 충분히 나타내지 못하는 한계를 나타내고 있다. 또한 사업비를 기준한 진도율 방식을 적용할 경우에는 시설물의 물리적 구성 정도 표현이 실제적이지 못하고, 여건 변화에 따라 사업비가 변경될 때에는 진도율도 변경되는 등의 문제점을 포함하고 있다.

따라서 본 연구에서는 대규모 도시 건설사업에서 도시가 완성되는 정도를 실질적이며 효과적으로 표현하기 위하여, 도시의 주요 시설에 대

한 전문가의 의견을 반영한 분야별 가중치를 선정하고 레벨별 가중치에 대한 집계 및 분석 체계를 구축하였다. 또한 이를 반영한 S-도시 건설사업에 대한 진도율 관리 사례 연구를 수행하고 정보시스템을 적용하여, 대규모 도시 건설사업에 대한 진도율 관리의 효율적인 운영방안을 제시하고자 한다.

이를 위해 도시 구성의 진도율 정보를 관리 수준에 따라 계층화하였으며, 대규모 도시를 구성하는 주요 시설의 중요도에 대한 가중치 산정을 위해서 도시건설 전문가와 사업관리 전문가 등을 대상으로 설문조사 및 면담을 수행하였다. 설문조사 방법은 계층적 구조를 가지는 문제에서 주관적인 평가 내용을 정리하여 좀 더 객관적이고 체계적인 결과를 얻을 수 있는 일반적인 방법인 AHP(Analytical Hierarchy Process) 기법을 사용하였다. 건설사업의 진행에 대한 입력 정보인 계약패키지 수준의 정보에 대해서는 설계, 구매, 시공패키지 등에 실행기성(EV : Earned Value) 개념을 기반한 단계별 관리점(Control Points)을 적용하여 기간별로 해당 업무의 객관적인 진도율을 산정하였다.

제시한 진도율 관리 모델의 활용성 검토를 위해 기 완성된 일부 기초생활권의 주요시설별 실적을 기준으로 시뮬레이션을 수행하여 기초생활권의 진도율에 따른 주요시설별 진도율을 제시하였다. 제시된 진도율을 참고하여 후속 기초생활권의 주요시설별 진행사항을 비교하고 필요 시 시설별 투자 선후에 대한 의사결정 지원이 가능하도록 하였다.

마지막으로 S-도시 주요 시설별 진도율에 적정한 모듈을 도출하여, 이를 반영한 대규모 도시 건설사업에 관한 정보시스템을 구현하였다.

본 논문에서 제시된 진도율관리 방안과 정보시스템을 대규모 도시 건설사업 등에 활용한다면 국가 예산의 효율적 활용과 국민의 편의성 증대 등에 기여할 것이며, 또한 해외의 대규모 도시 건설 사업에 본 연구결과와 진도율 관리 체계를 적용한다면 관련 산업 수출로 인하여 국가경쟁력 증진에 이바지할 수 있을 것이다.

주요어 : 프로젝트 관리, 진도관리, 대규모 도시 건설, 시설물별 가중치, 단계별 관리점(Control Points)

Appendix

1. Survey sheet for weighing of key facilities
2. Interview sheet for weighing of key facilities
3. Work Breakdown Structure (WBS)
4. Sectional Breakdown Structure (SBS)
5. Project entity identification code
6. Construction stage code

[Appendix 1] Survey sheet for weighing of key facilities

설 문 조 사 서

【대규모 도시 건설사업의 진도율관리 모델에 관한 연구】

안녕하십니까?
바쁘신 중에도 불구하고 귀중한 시간을 내어 주셔서 진심으로 감사드립니다.

저는 현재 『대규모 도시 건설사업의 진도율관리 모델에 관한 연구』논문을 준비 중에 있습니다. 이와 관련하여 대규모 건설사업의 진도관리 대상 시설물의 가중치를 도출하기 위한 설문조사를 하고자 합니다.

본 설문은 익명으로 처리되며, 학문적 연구목적 이외에는 사용되거나 공표되지 않습니다. 또한 개인의 어떠한 불이익도 초래하지 않을 것을 약속드립니다.
전문가 여러분의 성의있는 답변 부탁드리겠습니다.

다시 한 번 귀하의 협조에 감사드리며 건강과 행운이 함께 하시길 기원합니다.

감사합니다.

2014.12.
서울대학교 공과대학 건설환경공학부
건설혁신연구실 박사과정
연구자 : 고성진

본 설문과 관련된 문의는 아래로 연락주시기 바랍니다.

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연 구 개 요

■ 대규모 도시 건설사업의 진도율관리 모델에 관한 연구

최근 국내에서 진행되고 있는 대규모 도시 건설사업에서 사업의 완성을 나타내는 진도관리 지표로 총사업비 집행현황과 종합 진도율을 사용하고 있다. 이 두 지표는 목표점이 분명하다는 장점이 있는 반면, 총사업비 집행현황의 경우 도시건설이 진행되기 전 총사업비의 약 20~ 30%에 해당하는 용지비 집행을 포함하므로 도시의 완성률을 실질적으로 나타나기에는 한계가 있다. 또한 종합 진도율의 경우 용지비를 제외한 시설물의 사업 진도율을 기준으로 도시의 완성을 측정하는 지표로 활용하고 있지만, 도시 건설사업에 참여하는 정부 및 사업시행자의 총사업비 외 사업 중 도시 완성에 필요한 전기, 가스, 통신, 냉·난방 시설 등의 민간사업 정보가 반영되지 않아 도시의 완성을 나타내는 진도관리 지표라고 하기에는 충분하지 않다고 할 수 있다. 따라서 본 연구에서는 대규모 도시 건설사업을 구성하는 부지조성, 교통시설, 도시공급시설 등의 주요 시설별 가중치를 단순한 사업비를 기준으로 적용하지 않고 도시 구성의 중요도에 따라 산정하며, 정부 및 사업시행자의 총사업비 외 사업인 전기, 가스, 통신 등 도시 구성에 필수적인 민간시설을 포함하고자 한다. 이에 대한 가중치는 각 시설분야의 특성 등이 상이하고 일관적 기준 적용이 용이하지 않아, 도시건설 전문가 및 실무자와 사업관리 전문가들을 대상으로 도시 주요시설의 중요도에 대하여 본 설문조사를 수행하여 그 결과를 적용하고자 한다.

이에 따라 본 논문에서는 도시 건설사업의 완성도를 측정하는 새로운 진도관리 지표를 제시하고자 한다. 이를 위해 대규모 도시개발에 필요한 시설물을 바탕으로 업무분류체계(WBS)[38]를 구축하고, 이를 기반으로 도시 완성의 대상이 되는 시설물을 선정하여 시설물의 추진과정인 기획, 인허가, 설계, 시공, 시운전, 이관 등 시설물에 따른 단위작업을 개발하고자

38) Work Breakdown Structure

한다. 각각의 단위작업에 대한 가중치를 산정하여 실제적인 도시 건설의 완성률을 나타내고자 한다.

이를 통해 도시 완성 진도의 지표를 수립하고 선·후행 관계를 정립함으로써 효과적인 도시 건설의 진도관리와 체계적인 도시건설을 위한 "시설별 가중치 환산 도시완성률"기반의 진도관리 모델을 제시하고자 한다. 본 조사는 익명으로 처리되며, 학문적 연구목적 이외에는 사용되거나 공표되지는 않습니다.

전문가 여러분의 성의 있는 답변 부탁드리겠습니다.

1. 도시 건설사업의 진도율 산정 대상범위에 대한 타당성 조사

■ 대규모 도시 건설사업의 진도관리의 지표로 총사업비 집행현황과 종합 진도율을 일반적으로 사용하고 있으나, 도시 전체의 완성을 표현하는데 한계가 있습니다. 이에 본 연구에서는 기존 관리 대상인 정부 직발주 시설과 사업시행자 시설 외에 전기, 가스 등의 도시공급시설, 공동주택 및 상가 등의 민간시설 그리고 학교 및 정부출연연구기관 등의 기타 정부시설 등을 포함하여 도시를 구성하는 시설물 전체를 대상범위로 하였습니다.

(1) 대상범위 선정에 대해 적절한지 아래 표에 답해주십시오.

구 분	매우 적절함				매우 부적절함
범위 선정의 적절성	①	②	③	④	⑤

(2) 적절하지 않다면 그 이유는 무엇이라고 생각하십니까?
( )

(3) 그 외 포함되어야 할 시설물이 있다면 적어주십시오.
( )

(4) 도시 완성률 대상범위와 관련된 의견이 있으시면 자유롭게 적어주시면 감사하겠습니다.
( )

2. 시설물 가중치에 대한 설문조사

Ⅰ. 평가요소의 설명

■ 본 연구에서는 대규모 도시 건설사업의 특징에 근거하여 도시 완성에 필요한 시설물을 부지조성, 교통, 도시공급, 공공시설, 문화·복지, 교육, 주거, 상업, 기타시설 9가지를 선정하였습니다. 각각 평가요소에 해당하는 대표 시설물은 아래의 표와 같습니다.

평가요소	대표 시설물
부지조성시설	부지조성, 조경, 철거, 문화재 발굴 등
교통시설	광역도로, 도시 내부순환로, 도시접근로 등
도시공급 및 처리시설	전기, 가스, 통신, 집단에너지, 수질복원시설, 폐기물처리시설 등
공공시설	중앙행정, 국가행정, 지방행정, 정부출연연구기관 등
문화복지시설	주민센터, 사회복지시설, 체육시설, 문화시설 등
교육시설	유치원, 초·중·고등학교, 특수학교, 대학교 등
주거시설	공동주택(아파트, 오피스텔, 도시형생활주택), 단독주택 등
상업 및 업무시설	근린상가, 백화점, 복합상업시설과 업무용시설 등
기타시설	의료시설, 종교, 장례, 주유시설 등 민간시설

Ⅱ. 쌍대비교 척도 기준

중요도	정의	설명
1	비슷함	어떤 기준에 대하여 두 항목이 비슷한 공헌도를 가진다고 판단됨
3	약간 중요함	경험과 판단에 의하여 한 항목이 다른 항목보다 약간 선호됨
5	중요함	경험과 판단에 의하여 한 항목이 다른 항목보다 강하게 선호됨
7	매우 중요함	경험과 판단에 의하여 한 항목이 다른 항목보다 매우 강하게 선호됨
2,4,6	위 값들의 중간값	경험과 판단에 의하여 비교값이 위 값들의 중간 값에 해당한다고 판단될 경우 사용함

Ⅲ. 설문작성 방법

■ 예시

평가항목	매우중요		중요		약간중요		비슷		약간중요		중요		매우중요	평가항목
부지조성 시설	✓													교통시설

＊ 항목을 평가함에 있어 부지조성시설과 교통시설 중 부지조성시설이 매우 중요하다고 판단되시면, 위와 같이 기입하면 됩니다.

Ⅳ. 시설물간 중요도 평가(본 설문)

평가항목	매우중요		중요		약간중요		비슷		약간중요		중요		매우중요	평가항목
부지조성시설	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	교통시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	도시공급 및 처리 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	공공시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	문화복지시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	교육시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	주거시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	상업 및 업무시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	기타시설

평가항목	매우 중요		중요		약간 중요		비슷		약간 중요		중요		매우 중요	평가항목
교통 시설	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	도시공급 및 처리 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	공공 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	문화 복지 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	교육 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	주거 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	상업 및 업무 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	기타 시설

평가항목	매우중요		중요		약간중요		비슷		약간중요		중요		매우중요	평가항목
도시공급 및 처리시설	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	공공 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	문화 복지 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	교육 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	주거 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	상업 및 업무 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	기타 시설

평가항목	매우중요		중요		약간중요		비슷		약간중요		중요		매우중요	평가항목
공공 시설	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	문화 복지 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	교육 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	주거 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	상업 및 업무 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	기타 시설

평가항목	매우 중요		중요		약간 중요		비슷		약간 중요		중요		매우 중요	평가항목
문화 복지 시설	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	교육 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	주거 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	상업 및 업무 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	기타 시설

평가항목	매우 중요		중요		약간 중요		비슷		약간 중요		중요		매우 중요	평가항목
교육 시설	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	주거 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	상업 및 업무 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	기타 시설

평가항목	매우중요		중요		약간중요		비슷		약간중요		중요		매우중요	평가항목
주거 시설	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	상업 및 업무 시설
	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	기타 시설

평가항목	매우중요		중요		약간중요		비슷		약간중요		중요		매우중요	평가항목
상업 및 업무 시설	⑦	⑥	⑤	④	③	②	①	②	③	④	⑤	⑥	⑦	기타 시설

3. 기초 설문조사

1) 귀하의 소속은 어디입니까?
① 정부부처 ② 공공기관 ③ 시공사 ④ 학교 및 연구소 ⑤ CM회사
⑥ 기타( )

2) 귀하의 담당업무는 무엇입니까?
① 발주 ② 감독 ③ 시공 ④ 연구개발 ⑤ 기타 ( )

3) 귀하의 경력은 몇 년입니까?
① 5년 미만 ② 5년 이상 ~10년 미만
③ 10년 이상 ~ 15년 미만 ④ 15년 이상 ~20년 미만
⑤ 20년 이상

4) 귀하가 가졌던 프로젝트 중에서 대규모 도시 건설사업에 관련되어 수행하였던 프로젝트는 몇 회입니까?
① 없음 ② 1회
③ 2회 ④ 3회
⑤ 4회 이상

설문조사에 응해주셔서 대단히 감사합니다.

[Appendix 2] Interview sheet for weighing of key facilities

면 담 조 사 서

【대규모 도시 건설사업의 진도율관리 모델에 관한 연구】

안녕하십니까?
바쁘신 중에도 불구하고 귀중한 시간을 내어 주셔서 진심으로 감사드립니다.

저는 현재 『대규모 도시 건설사업의 진도율관리 모델에 관한 연구』논문을 준비 중에 있습니다. 이와 관련하여 새롭게 제시하는 **대규모 도시건설의 진도율관리 모델**에 대한 면담조사를 하고자 합니다.

본 조사는 익명으로 처리되며, 학문적 연구목적 이외에는 사용되거나 공표되지 않습니다. 또한 개인의 어떠한 불이익도 초래하지 않을 것을 약속드립니다.
전문가 여러분의 성의있는 답변 부탁드리겠습니다.

다시 한 번 귀하의 협조에 감사드리며 건강과 행운이 함께 하시길 기원합니다.

감사합니다.

2016. 08.
서울대학교 공과대학 건설환경공학부
건설혁신연구실 박사과정
연구자 : 고성진

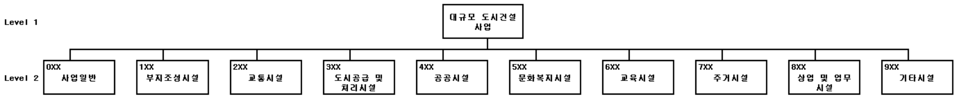
본 설문과 관련된 문의는 아래로 연락주시기 바랍니다.
담당자: 고성진
연락처: 010-4447-4160, kosj1120@hanmail.net

1. 연구 개요

■ 최근 국내에서 진행되고 있는 대규모 도시 건설사업에서 사업의 완성을 나타내는 진도관리 지표로 총사업비 집행현황과 종합 진도율을 사용하고 있다. 이 두 지표는 목표점이 분명하다는 장점이 있는 반면, 총사업비 집행현황의 경우 도시건설이 진행되기 전 용지비 집행을 포함하므로 도시의 완성률을 실질적으로 나타나기에는 한계가 있다. 또한 종합 진도율의 경우 용지비를 제외한 시설물의 사업 진도율을 기준으로 도시의 완성을 측정하는 지표로 활용하고 있지만, 도시 건설사업에 참여하는 정부 및 사업시행자의 총사업비 외 사업 중 도시 완성에 필요한 공동주택, 상가 등의 민간사업 정보가 반영되지 않아 도시의 완성을 나타내는 진도관리 지표라고 하기에는 충분하지 않다고 할 수 있다. 따라서 본 연구에서는 **진도율 관리를 위한 기초자료를 구축**하고 대규모 도시 건설사업을 구성하는 부지조성, 교통시설, 도시공급시설 등의 주요 시설별 가중치를 단순한 **사업비를 기준으로 적용하지 않고 도시 구성의 중요도에 따라 산정**하였으며 정부 및 사업시행자의 총사업비 외 사업인 공동주택, 상가 등 도시 구성에 필수적인 민간시설을 포함하였다.

□ 업무분류체계(WBS: Work Breakdown Structure)

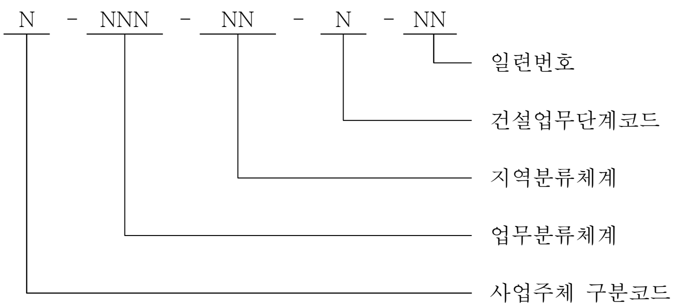
- 국고 및 사업시행자분, 개별사업자분, 주요 민간 사업자분 등을 포함한 대규모 도시 건설사업의 진도율 관리를 위한 업무분류체계(WBS : Work Breakdown Structure)를 개발하여 계층적 구조로 구성



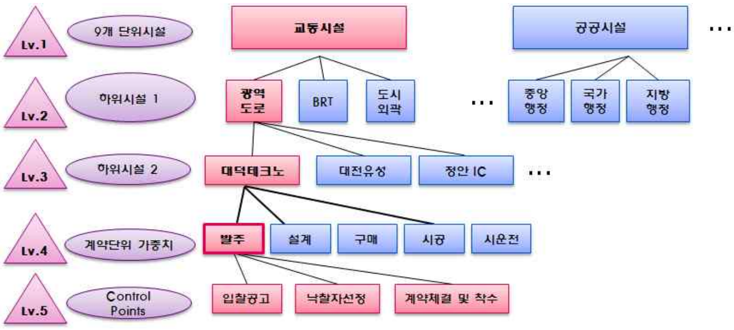
* 사업일반(0XX), 부지조성시설(1XX), 교통시설(2XX), 도시공급 및 처리시설(3XX), 공공시설(4XX), 문화복지시설(5XX), 교육시설(6XX), 주거시설(7XX), 상업 및 업무시설(8XX), 기타시설(9XX)

□ 단위작업번호체계(ANS: Activity Numbering System)

- 대규모 도시 건설사업에서 활용 가능한 업무분류체계와 지역분류체계를 포함하고, 주요 시설에 대해 분야별 및 지역별 진도의 계획 대비 실적과 성과 분석 등에 활용하여 향후 예측 및 분석이 가능하도록 사업번호체계의 하나인 단위작업번호체계를 개발



* 대규모 도시 건설사업을 구성하는 부지조성, 교통시설, 도시공급시설 등의 주요 시설별 가중치를 단순한 사업비 비중의 진도율 기준으로 적용하지 않고 도시 구성의 중요도(주요시설 Level 1)에 따라 산정하며, 공공사업뿐만 아니라 공동주택과 상업시설 등의 민간사업도 포함



Level별 가중치 산정 흐름

□ 주요시설(Level 1)의 가중치 산정

- 대규모 도시를 구성하는 시설물에 대한 가중치는 각 시설분야의 특성 등이 상이하고 일관적 기준 적용이 용이하지 않아 도시건설 전문가, 사업관리 전문가, 사업관리 실무자 등을 대상으로 대규모 도시 주요 시설의 중요도에 대하여 다음과 같은 설문조사를 수행하여 결과를 도출

주요시설(Level 1)	백분율(%)	중요순위
부지조성	12.9	3
교통시설	18.7	1
도시공급 및 처리시설	13.7	2
공공시설	9.3	6
문화복지시설	7.4	8
교육시설	11.3	5
주거시설	13.2	4
상업 및 업무시설	7.8	7
기타시설	5.7	9

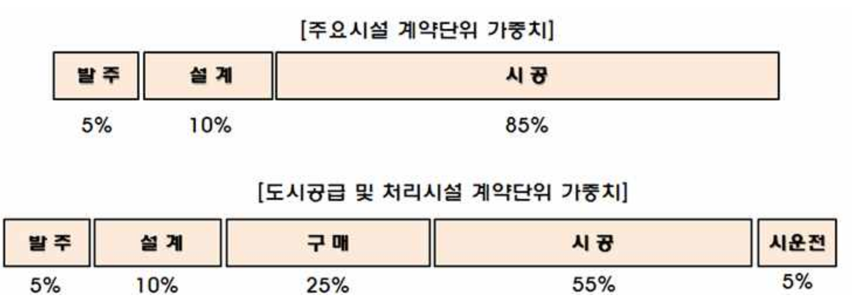
□ 주요시설을 구성하는 하위시설(Level 2,3) 가중치 산정

- 대규모 도시를 구성하는 주요 시설(Level 1)의 하위 시설(Level 2,3)에 대한 가중치 산정 기준은 각 하위 시설의 특성을 반영하여 적용

주요 시설(Lev.1)	하위시설(Lev.2,3)	가중치 선정 기준	비고
부지조성	부지정지, 조경 등	면적	
교통시설	광역도로, 도시외곽, 교량 등	연장	
도시공급 및 처리시설	자동크린넷, 수질복원센터, 폐기물처리시설 등	사업비	
공공시설	공공청사, 시청, 교육청 등	연면적	
문화복지시설	복합커뮤니티센터,문화시설 등	연면적	
교육시설	유•초•중•고, 대학 등	연면적	
주거시설	공동주택, 단독주택 등	연면적	
상업 및 업무시설	상가, 복합상업시설 등	연면적	
기타시설	의료, 종교, 주유 등	연면적	

□ 주요시설별 계약단위(Level 4) 가중치 산정

- 설계와 시공 외 도시 구축 시 연관된 후속 공사에 끼치는 영향을 고려하여 발주단계를 추가하였고, 기계설비 등이 포함되는 도시공급 및 처리시설의 경우는 구매 및 시운전을 추가로 반영



□ 단계별 관리점(Control Points, Level 5) 설정

- 발주, 설계, 구매, 시운전의 경우 단계별 관리점(Control Points)을 설정하고 가중치를 별도로 부여하여 각 단계별로 수행 실적을 측정(국내·외 대형사업 참조 및 전문가 의견 반영)

구분	단계	관리점	가중치	가중치 누계
발주	Step 1	입찰 공고	50%	50%
	Step 2	낙찰자 선정	40%	90%
	Step 3	계약체결 및 착수	10%	100%

구분	단계	관리점	가중치	가중치 누계
설계	Step 1	승인용 제출	30%	30%
	Step 2	시공용 제출	50%	80%
	Step 3	최종 제출	20%	100%

구분	단계	관리점	가중치	가중치 누계
구매	Step 1	발주(Purchase Order)	35%	35%
	Step 2	제작 및 검수	50%	85%
	Step 3	운반 및 현장 반입	15%	100%

구분	단계	관리점	가중치	가중치 누계
시운전	Step 1	사전 점검 및 시험 착수	30%	30%
	Step 2	종합시운전 착수	50%	80%
	Step 3	종합시운전 종료	20%	100%

- 시공단계의 경우 각 계약자 예정공정표의 주요 업무 항목을 기준으로 대표 물량을 선정하여 ㎡, km 등의 물리적 측정 단위를 이용

2. 진도율 관리 모델 검증

■ 본 연구에서 제시하고자 하는 도시건설에 대한 진도관리 모델을 구축하였을 경우, 기존 진도관리와 비교하여 차별성을 가져야 할 지표를 기존 연구문헌39)을 참고하고, 전문가 설문 및 면담을 거쳐 5가지로 지표를 최종 도출하였습니다. 제시한 5가지 지표에 대하여 기존 모델과 새로운 진도율 관리 모델을 비교·평가하여 주시기 바랍니다.

[평가지표]

지표	정의
타당성	제안 모델의 타당성 정도
효율성	진도율 관리 측면에서의 효율성 정도
실무활용성	제안 모델의 실무적인 차원에서 활용되는 정도
적용적용성	타 대규모 도시건설 적용 가능 정도
독창성	제안 모델의 기존 진도관리 방식과 비교 시 독창성 정도

[응답예시] 타당성면에서 제시된 진도관리 모델이 타당성이 높다면 높음에 체크하시면 됩니다.

구 분	매우 높음	높음	보통	낮음	매우 낮음
타당성	①	√	③	④	⑤

■ 설문을 시작해 주십시오.

(1) 본 연구에서 제시하는 진도관리 모델이 타당하다고 생각하십니까?

39) -Isola, Alphonse D., Value Engineering Practical Applications, RS Means, 1997
-현창택 외, 공공 건설 프로그램의 기획단계 VE를 위한 다차원 품질모델, 한국건설관리학회, 2013
-정호근 외, 공동주택의 설계VE단계에서 주체별 요구항목 분석을 통한 대상선정 개선방안, 한국건설관리학회, 2008

구 분	매우 높음	높음	보통	낮음	매우 낮음
타당성	①	②	③	④	⑤

(2) 본 연구에서 제시하는 진도관리 모델이 효율적이라고 생각하십니까?

구 분	매우 높음	높음	보통	낮음	매우 낮음
효율성	①	②	③	④	⑤

(3) 본 연구에서 제시하는 진도관리 모델의 실무활용성에 대하여 체크해 주십시오.

구 분	매우 높음	높음	보통	낮음	매우 낮음
실무활용성	①	②	③	④	⑤

(4) 본 연구에서 제시하는 진도관리 모델의 타 유사 프로젝트의 적용가능성에 대하여 체크해 주십시오.

구 분	매우 높음	높음	보통	낮음	매우 낮음
적용가능성	①	②	③	④	⑤

(5) 본 연구에서 제시하는 진도관리 모델은 독창성이 높다고 판단하십니까?

구 분	매우 높음	높음	보통	낮음	매우 낮음
독창성	①	②	③	④	⑤

＊ 그 외 검토 의견이 있으시면 자유롭게 남겨주십시오.

( )

3. 기초 설문조사

1) 귀하의 소속은 어디입니까?
① 정부부처 ② 공공기관 ③ 학교 및 연구소 ④ CM회사 ⑤ 기타

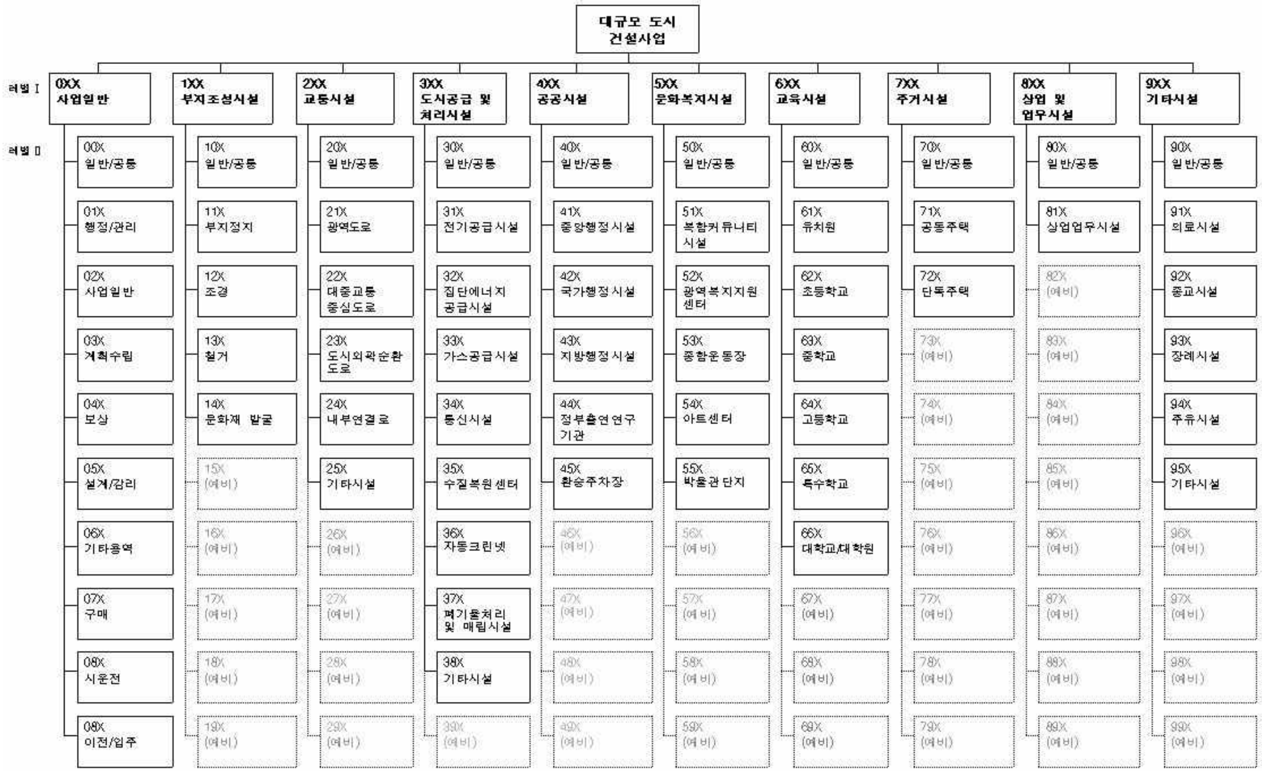
2) 귀하의 담당업무는 무엇입니까?
① 발주 ② 감독 ③ 계획 ④ 연구개발 ⑤ 기타 (   )

3) 귀하의 경력은 몇 년입니까?
① 5년 미만   ② 5년 이상 ~10년 미만
③ 10년 이상 ~ 15년 미만   ④ 15년 이상 ~20년 미만
⑤ 20년 이상

4) 귀하가 가졌던 프로젝트 중에서 대규모 도시 건설사업에 관련되어 수행하였던 프로젝트는 몇 회입니까?
① 없음   ② 1회
③ 2회   ④ 3회
⑤ 4회 이상

조사에 응해주셔서 대단히 감사합니다.

[Appendix 3] Work Breakdown Structure (WBS)



레벨 I

- 0XX 사업일반

레벨 II / 레벨 III

- 00X 일반/공통
  - 000 일반/공통
  - 001 (예비)
  - 002 (예비)
  - 003 (예비)
  - 004 (예비)
  - 005 (예비)
  - 006 (예비)
  - 007 (예비)
  - 008 (예비)
  - 00Z 기타
- 01X 행정관리
  - 010 일반/공통
  - 011 일반행정
  - 012 자금/예산관리
  - 013 자산관리
  - 014 전산관리
  - 015 홍보/마케팅
  - 016 인허가
  - 017 교육훈련
  - 018 민원업무 (보상제외)
  - 01Z 기타
- 02X 사업관리
  - 020 일반/공통
  - 021 사업기획
  - 022 사업통제
  - 023 계약관리
  - 024 품질/안전/환경
  - 025 시공관리
  - 026 정보관리
  - 027 자료관리
  - 028 유지보수
  - 02Z 기타
- 03X 계획수립
  - 030 일반/공통
  - 031 기본계획
  - 032 광역도시계획
  - 033 이전계획
  - 034 개발계획
  - 035 실시계획
  - 036 지구단위계획
  - 037 주변지역 관리계획
  - 038 정보화 전략계획
  - 03Z 기타
- 04X 보상
  - 040 일반/공통
  - 041 토지보상
  - 042 업권보상
  - 043 기타보상
  - 044 보상관련 민원업무
  - 045 (예비)
  - 046 (예비)
  - 047 (예비)
  - 048 (예비)
  - 04Z 기타
- 05X 설계/감리
  - 050 일반/공통
  - 051 설계경기
  - 052 기본 및 실시설계
  - 053 기본설계
  - 054 실시설계
  - 055 설계감리
  - 056 시공감리
  - 057 (예비)
  - 058 (예비)
  - 05Z 기타
- 06X 기타용역
  - 060 일반/공통
  - 061 연구용역
  - 062 조사용역
  - 063 타당성조사
  - 064 교통영향평가
  - 065 환경영향평가
  - 066 사후환경 영향평가조사
  - 067 (예비)
  - 068 (예비)
  - 06Z 기타
- 07X 구매
  - 070 일반/공통
  - 071 주요설비
  - 072 자재
  - 073 장비
  - 074 (예비)
  - 075 (예비)
  - 076 (예비)
  - 077 (예비)
  - 078 (예비)
  - 07Z 기타
- 08X 시운전
  - 080 일반/공통
  - 081 시운전
  - 082 (예비)
  - 083 (예비)
  - 084 (예비)
  - 085 (예비)
  - 086 (예비)
  - 087 (예비)
  - 088 (예비)
  - 08Z 기타
- 09X 이전/입주
  - 090 일반/공통
  - 091 정부청사이전
  - 092 지자체이전
  - 093 정부출연기관 이전
  - 094 입주
  - 095 (예비)
  - 096 (예비)
  - 097 (예비)
  - 098 (예비)
  - 09Z (예비)

레벨 Ⅰ

- 1XX 부지조성시설

레벨 Ⅱ / 레벨 Ⅲ

- 10X 일반/공통
  - 100 일반/공통
  - 101 (예비)
  - 102 (예비)
  - 103 (예비)
  - 104 (예비)
  - 105 (예비)
  - 106 (예비)
  - 107 (예비)
  - 108 (예비)
  - 10Z 기타
- 11X 부지정지
  - 110 일반/공통
  - 111 부지정지
  - 112 (예비)
  - 113 (예비)
  - 114 (예비)
  - 115 (예비)
  - 116 (예비)
  - 117 (예비)
  - 118 (예비)
  - 11Z 기타
- 12X 조경
  - 120 일반/공통
  - 121 조경
  - 122 (예비)
  - 123 (예비)
  - 124 (예비)
  - 125 (예비)
  - 126 (예비)
  - 127 (예비)
  - 128 (예비)
  - 12Z 기타
- 13X 철거
  - 130 일반/공통
  - 131 철거
  - 132 건설전 폐기물처리
  - 133 (예비)
  - 134 (예비)
  - 135 (예비)
  - 136 (예비)
  - 137 (예비)
  - 138 (예비)
  - 13Z 기타
- 14X 문화재발굴
  - 140 일반/공통
  - 141 문화재시굴
  - 142 문화재발굴
  - 143 (예비)
  - 144 (예비)
  - 145 (예비)
  - 146 (예비)
  - 147 (예비)
  - 148 (예비)
  - 14Z 기타
- 15X (예비)
  - 150 (예비)
  - 151 (예비)
  - 152 (예비)
  - 153 (예비)
  - 154 (예비)
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  - 156 (예비)
  - 157 (예비)
  - 158 (예비)
  - 15Z (예비)
- 16X (예비)
  - 160 (예비)
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  - 16Z (예비)
- 17X (예비)
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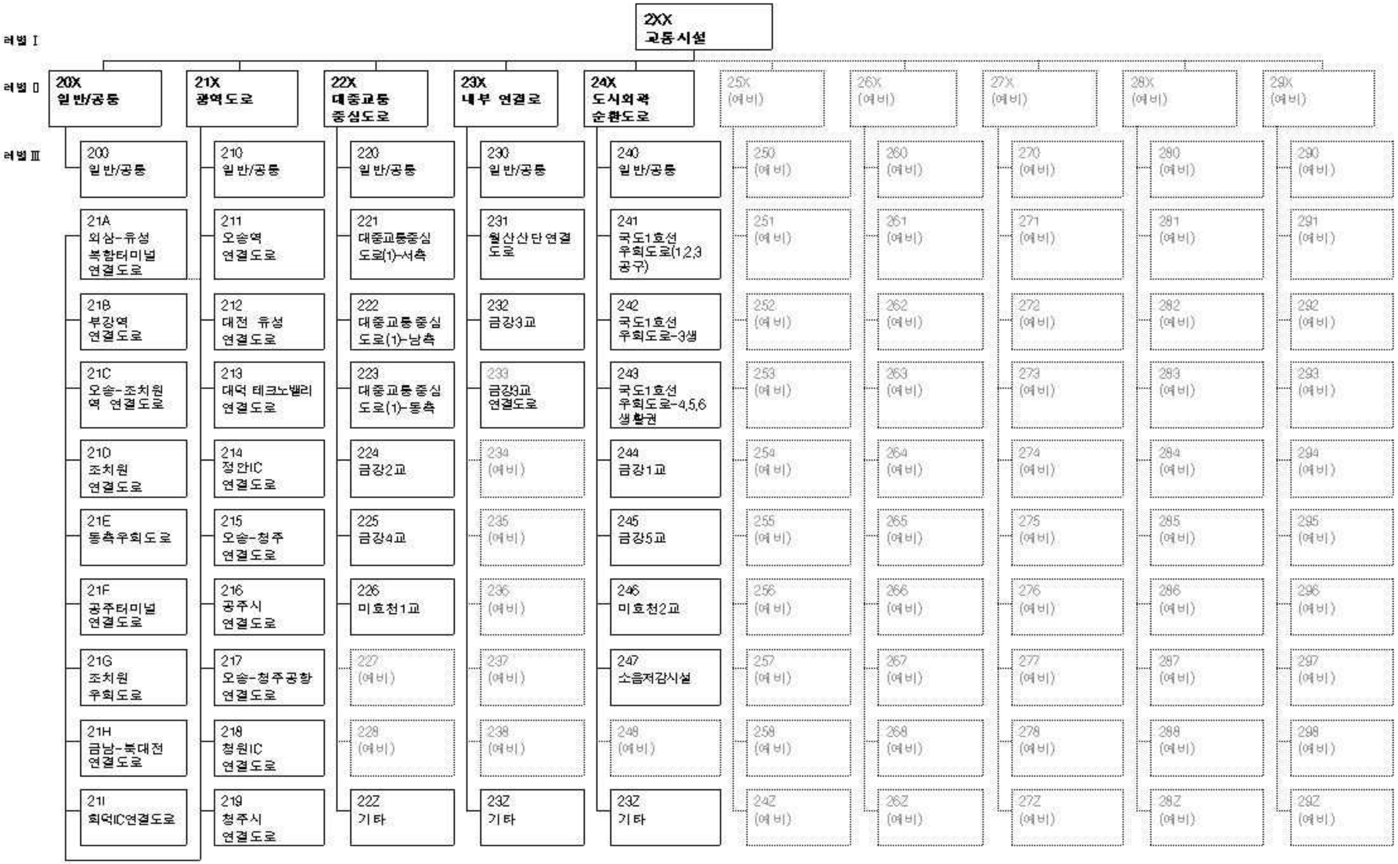
  - 197 (예비)
  - 198 (예비)
  - 19Z (예비)



레벨 I
레벨 II
레벨 III
2XX 교통시설
20X 일반/공통
21X 광역도로
22X 대중교통 중심도로
23X 내부 연결로
24X 도시외곽 순환도로
25X (예비)
26X (예비)
27X (예비)
28X (예비)
29X (예비)
200 일반/공통
21A 외삼-유성 복합터미널 연결도로
21B 부강역 연결도로
21C 오송-조치원 역 연결도로
21D 조치원 연결도로
21E 동측우회도로
21F 공주터미널 연결도로
21G 조치원 우회도로
21H 금남-북대전 연결도로
21I 회덕IC연결도로
210 일반/공통
211 오송역 연결도로
212 대전 유성 연결도로
213 대덕 테크노밸리 연결도로
214 정안IC 연결도로
215 오송-청주 연결도로
216 공주시 연결도로
217 오송-청주공항 연결도로
218 청원IC 연결도로
219 청주시 연결도로
220 일반/공통
221 대중교통중심 도로(1)-서측
222 대중교통중심 도로(1)-남측
223 대중교통중심 도로(1)-동측
224 금강2교
225 금강4교
226 미호천1교
227 (예비)
228 (예비)
22Z 기타
230 일반/공통
231 월산산단연결 도로
232 금강3교
233 금강3교 연결도로
234 (예비)
235 (예비)
236 (예비)
237 (예비)
238 (예비)
23Z 기타
240 일반/공통
241 국도1호선 우회도로(1,2,3 공구)
242 국도1호선 우회도로-3생
243 국도1호선 우회도로-4,5,6 생활권
244 금강1교
245 금강5교
246 미호천2교
247 소음저감시설
248 (예비)
23Z 기타
250 (예비)
251 (예비)
252 (예비)
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28Z (예비)
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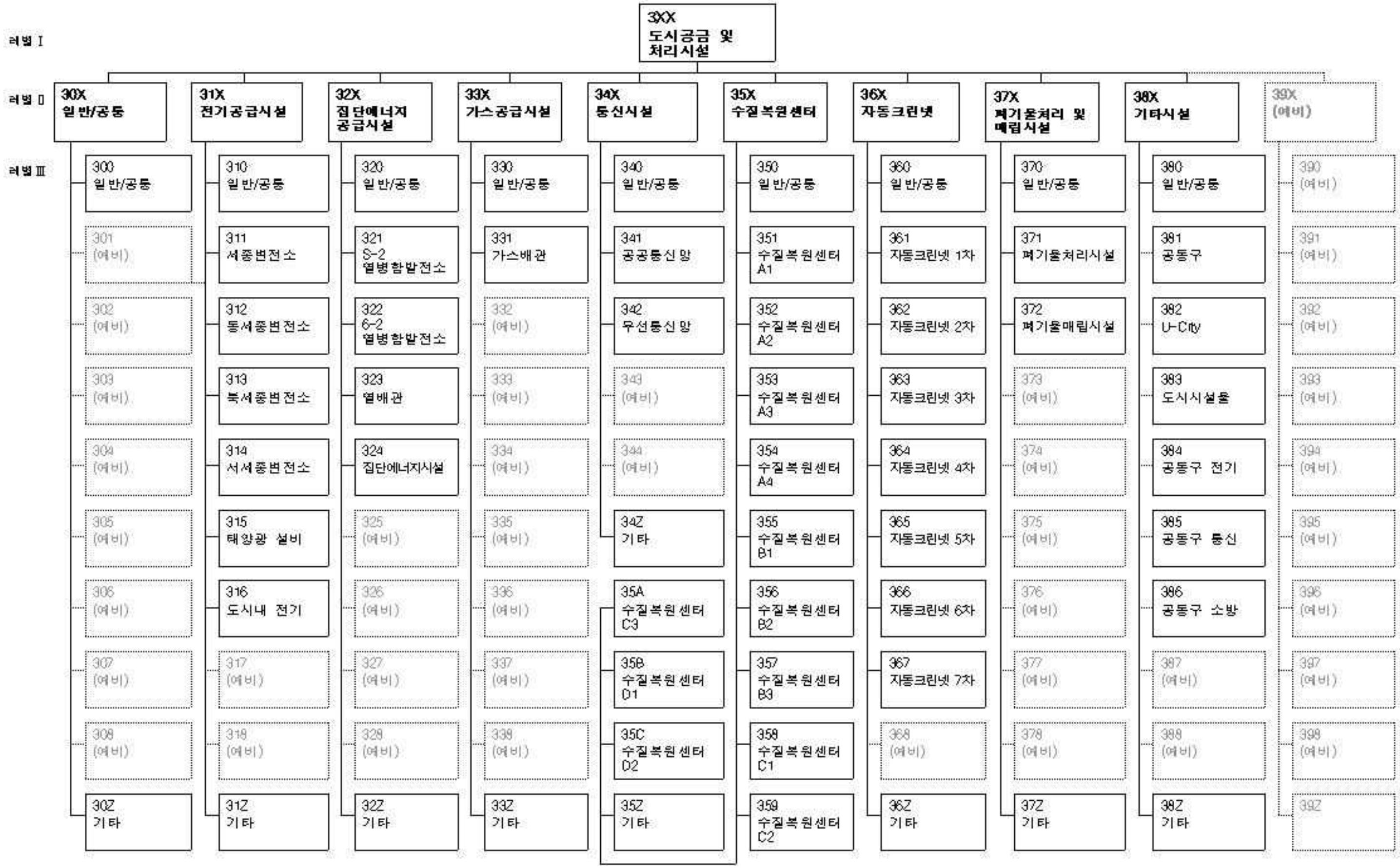
298 (예비)
29Z (예비)



레벨 I
레벨 II
레벨 III
3XX 도시공급 및 처리시설
30X 일반/공통
31X 전기공급시설
32X 집단에너지 공급시설
33X 가스공급시설
34X 통신시설
35X 수질복원센터
36X 자동크린넷
37X 폐기물처리 및 매립시설
38X 기타시설
39X (예비)
300 일반/공통
301 (예비)
302 (예비)
303 (예비)
304 (예비)
305 (예비)
306 (예비)
307 (예비)
308 (예비)
30Z 기타
310 일반/공통
311 세종변전소
312 동세종변전소
313 북세종변전소
314 서세종변전소
315 태양광 설비
316 도시내 전기
317 (예비)
318 (예비)
31Z 기타
320 일반/공통
321 S-2 열병합발전소
322 6-2 열병합발전소
323 열배관
324 집단에너지시설
325 (예비)
326 (예비)
327 (예비)
328 (예비)
32Z 기타
330 일반/공통
331 가스배관
332 (예비)
333 (예비)
334 (예비)
335 (예비)
336 (예비)
337 (예비)
338 (예비)
33Z 기타
340 일반/공통
341 공공통신망
342 무선통신망
343 (예비)
344 (예비)
34Z 기타
35A 수질복원센터 C3
35B 수질복원센터 D1
35C 수질복원센터 D2
35Z 기타
350 일반/공통
351 수질복원센터 A1
352 수질복원센터 A2
353 수질복원센터 A3
354 수질복원센터 A4
355 수질복원센터 B1
356 수질복원센터 B2
357 수질복원센터 B3
358 수질복원센터 C1
359 수질복원센터 C2
360 일반/공통
361 자동크린넷 1차
362 자동크린넷 2차
363 자동크린넷 3차
364 자동크린넷 4차
365 자동크린넷 5차
366 자동크린넷 6차
367 자동크린넷 7차
368 (예비)
36Z 기타
370 일반/공통
371 폐기물처리시설
372 폐기물매립시설
373 (예비)
374 (예비)
375 (예비)
376 (예비)
377 (예비)
378 (예비)
37Z 기타
380 일반/공통
381 공동구
382 U-City
383 도시시설물
384 공동구 전기
385 공동구 통신
386 공동구 소방
387 (예비)
388 (예비)
38Z 기타
390 (예비)
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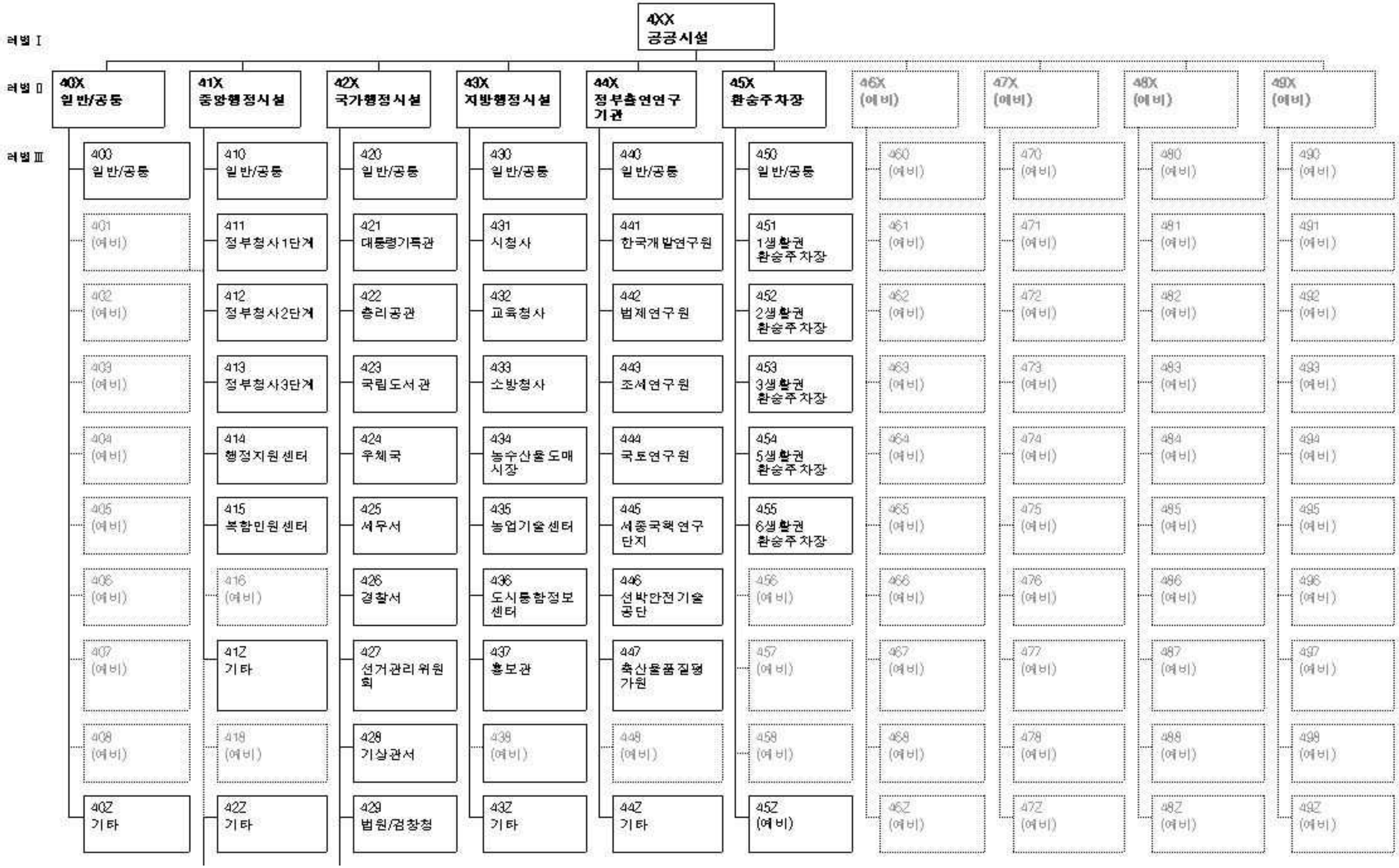
39Z


4XX 공공시설
레벨 I
레벨 II
레벨 III
40X 일반/공통
41X 중앙행정시설
42X 국가행정시설
43X 지방행정시설
44X 정부출연연구기관
45X 환승주차장
46X (예비)
47X (예비)
48X (예비)
49X (예비)
400 일반/공통
401 (예비)
402 (예비)
403 (예비)
404 (예비)
405 (예비)
406 (예비)
407 (예비)
408 (예비)
40Z 기타
410 일반/공통
411 정부청사1단계
412 정부청사2단계
413 정부청사3단계
414 행정지원센터
415 복합민원센터
416 (예비)
41Z 기타
418 (예비)
42Z 기타
420 일반/공통
421 대통령기록관
422 총리공관
423 국립도서관
424 우체국
425 세무서
426 경찰서
427 선거관리위원회
428 기상관서
429 법원/검찰청
430 일반/공통
431 시청사
432 교육청사
433 소방청사
434 농수산물도매시장
435 농업기술센터
436 도시통합정보센터
437 홍보관
438 (예비)
43Z 기타
440 일반/공통
441 한국개발연구원
442 법제연구원
443 조세연구원
444 국토연구원
445 세종국책연구단지
446 선박안전기술공단
447 축산물품질평가원
448 (예비)
44Z 기타
450 일반/공통
451 1생활권 환승주차장
452 2생활권 환승주차장
453 3생활권 환승주차장
454 5생활권 환승주차장
455 6생활권 환승주차장
456 (예비)
457 (예비)
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498 (예비)
49Z (예비)

레벨 I

- **5XX 문화복지시설**

레벨 II / 레벨 III

- **50X 일반/공통**
  - 500 일반/공통
  - 501 (예비)
  - 502 (예비)
  - 503 (예비)
  - 504 (예비)
  - 505 (예비)
  - 506 (예비)
  - 507 (예비)
  - 508 (예비)
  - 50Z 기타
- **51X 복합커뮤니티시설**
  - 510 일반/공통
  - 511 1생활권 복합커뮤니티
  - 512 2생활권 복합커뮤니티
  - 513 3생활권 복합커뮤니티
  - 514 4생활권 복합커뮤니티
  - 515 5생활권 복합커뮤니티
  - 516 6생활권 복합커뮤니티
  - 517 (예비)
  - 518 (예비)
  - 51Z 기타
- **52X 광역복지지원센터**
  - 520 일반/공통
  - 521 1생활권 광역복지지원센터
  - 522 2생활권 광역복지지원센터
  - 523 3생활권 광역복지지원센터
  - 524 4생활권 광역복지지원센터
  - 525 5생활권 광역복지지원센터
  - 526 6생활권 광역복지지원센터
  - 527 (예비)
  - 528 (예비)
  - 52Z 기타
- **53X 종합운동장**
  - 530 일반/공통
  - 531 종합운동장
  - 532 (예비)
  - 533 (예비)
  - 534 (예비)
  - 535 (예비)
  - 536 (예비)
  - 537 (예비)
  - 538 (예비)
  - 53Z 기타
- **54X 아트센터**
  - 540 일반/공통
  - 541 아트센터
  - 542 (예비)
  - 543 (예비)
  - 544 (예비)
  - 545 (예비)
  - 546 (예비)
  - 547 (예비)
  - 548 (예비)
  - 54Z 기타
- **55X 박물관**
  - 550 일반/공통
  - 551 국가기록박물관
  - 552 국립도시건축박물관
  - 553 국립디자인미술관
  - 554 국립디지털문화유산영상관
  - 555 어린이박물관
  - 556 (예비)
  - 557 (예비)
  - 558 (예비)
  - 55Z 기타
- **56X (예비)**
  - 540 (예비)
  - 541 (예비)
  - 542 (예비)
  - 543 (예비)
  - 544 (예비)
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  - 547 (예비)
  - 548 (예비)
  - 54Z (예비)
- **57X (예비)**
  - 550 (예비)
  - 551 (예비)
  - 552 (예비)
  - 553 (예비)
  - 554 (예비)
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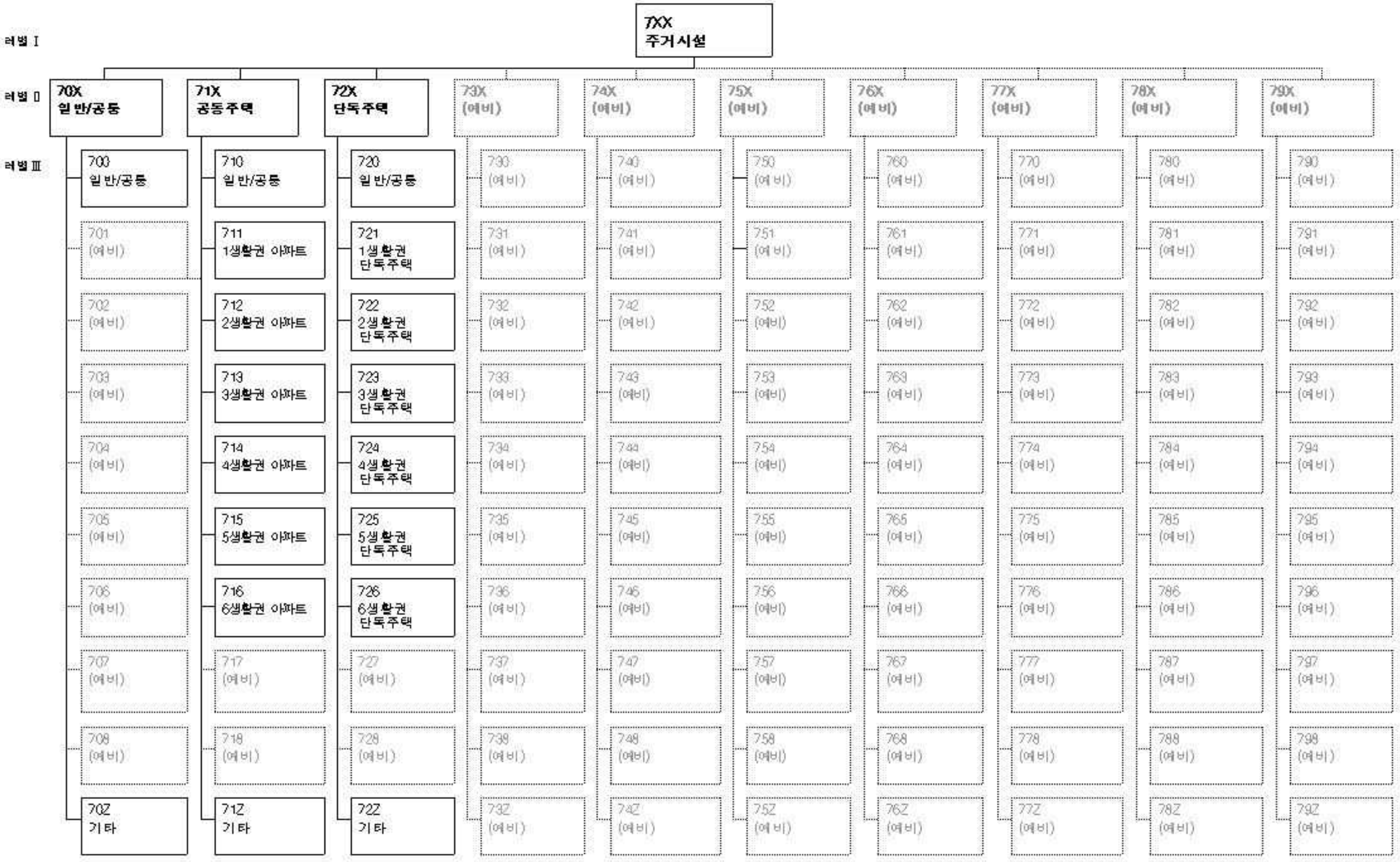
  - 557 (예비)
  - 558 (예비)
  - 55Z (예비)
- **58X (예비)**
  - 560 (예비)
  - 561 (예비)
  - 562 (예비)
  - 563 (예비)
  - 564 (예비)
  - 565 (예비)
  - 566 (예비)
  - 567 (예비)
  - 568 (예비)
  - 56Z (예비)
- **59X (예비)**
  - 570 (예비)
  - 571 (예비)
  - 572 (예비)
  - 573 (예비)
  - 574 (예비)
  - 575 (예비)
  - 576 (예비)
  - 577 (예비)
  - 578 (예비)
  - 57Z (예비)

레벨 I: 6XX 교육시설

레벨 II	60X 일반/공통	61X 유치원	62X 초등학교	63X 중학교	64X 고등학교	65X 특수학교	66X 대학교	67X (예비)	68X (예비)	69X (예비)
레벨 III	600 일반/공통	610 일반/공통	620 일반/공통	630 일반/공통	640 일반/공통	650 일반/공통	660 일반/공통	660 (예비)	681 (예비)	690 (예비)
	601 (예비)	611 1생활권 유치원	621 1생활권 초등학교	631 1생활권 중학교	641 1생활권 고등학교	651 특수학교	661 대학교	671 (예비)	682 (예비)	691 (예비)
	602 (예비)	612 2생활권 유치원	622 2생활권 초등학교	632 2생활권 중학교	642 2생활권 고등학교	652 (예비)	662 (예비)	672 (예비)	683 (예비)	692 (예비)
	603 (예비)	613 3생활권 유치원	623 3생활권 초등학교	633 3생활권 중학교	643 3생활권 고등학교	653 (예비)	663 (예비)	673 (예비)	684 (예비)	693 (예비)
	604 (예비)	614 4생활권 유치원	624 4생활권 초등학교	634 4생활권 중학교	644 4생활권 고등학교	654 (예비)	664 (예비)	674 (예비)	685 (예비)	694 (예비)
	605 (예비)	615 5생활권 유치원	625 5생활권 초등학교	635 5생활권 중학교	645 5생활권 고등학교	655 (예비)	665 (예비)	675 (예비)	686 (예비)	695 (예비)
	606 (예비)	616 6생활권 유치원	626 6생활권 초등학교	636 6생활권 중학교	646 6생활권 고등학교	656 (예비)	666 (예비)	676 (예비)	687 (예비)	696 (예비)
	607 (예비)	617 (예비)	627 (예비)	637 (예비)	647 (예비)	657 (예비)	667 (예비)	677 (예비)	688 (예비)	697 (예비)
	608 (예비)	618 (예비)	628 (예비)	638 (예비)	648 (예비)	658 (예비)	668 (예비)	678 (예비)	68Z (예비)	698 (예비)
	60Z 기타	61Z 기타	62Z 기타	63Z 기타	64Z 기타	65Z 기타	66Z 기타	67Z (예비)	67Z (예비)	69Z (예비)


레벨 I
레벨 II
레벨 III
7XX 주거시설
70X 일반/공통
71X 공동주택
72X 단독주택
73X (예비)
74X (예비)
75X (예비)
76X (예비)
77X (예비)
78X (예비)
79X (예비)
700 일반/공통
701 (예비)
702 (예비)
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706 (예비)
707 (예비)
708 (예비)
70Z 기타
710 일반/공통
711 1생활권 아파트
712 2생활권 아파트
713 3생활권 아파트
714 4생활권 아파트
715 5생활권 아파트
716 6생활권 아파트
717 (예비)
718 (예비)
71Z 기타
720 일반/공통
721 1생활권 단독주택
722 2생활권 단독주택
723 3생활권 단독주택
724 4생활권 단독주택
725 5생활권 단독주택
726 6생활권 단독주택
727 (예비)
728 (예비)
72Z 기타
730 (예비)
731 (예비)
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74Z (예비)
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80X 일반/공통
81X 상업업무시설
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812 2생활권 상업업무시설
813 3생활권 상업업무시설
814 4생활권 상업업무시설
815 5생활권 상업업무시설
816 6생활권 상업업무시설
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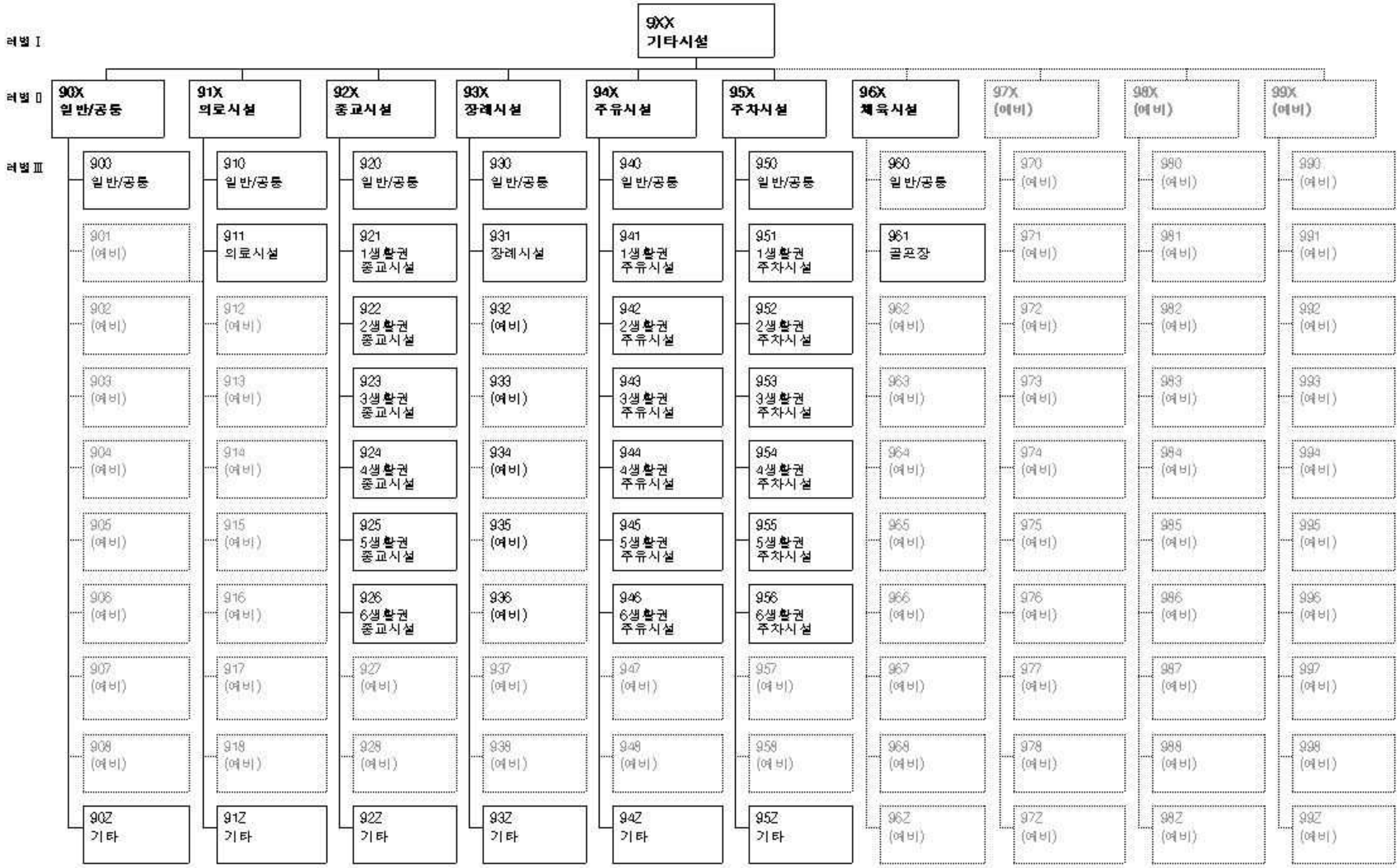

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종교시설
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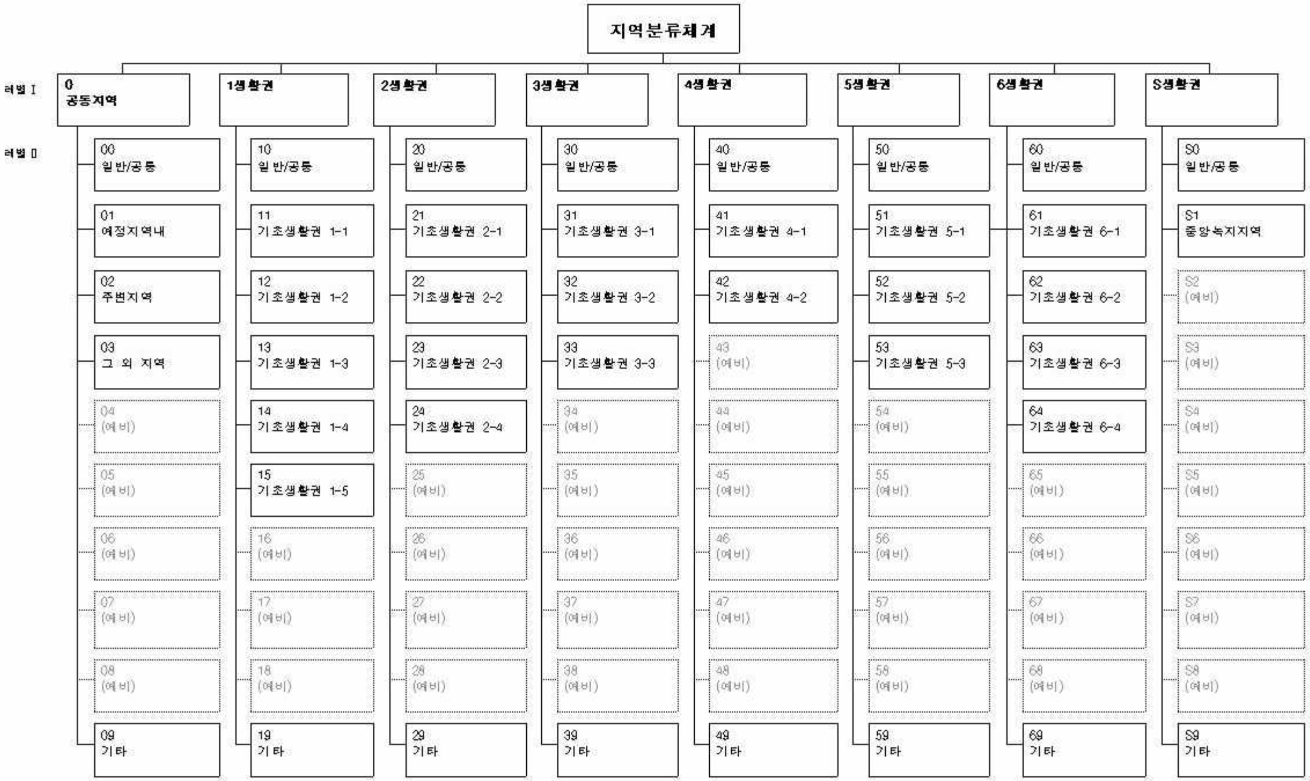
[Appendix 4] Sectional Breakdown Structure (SBS)



[Appendix 5] Project entity identification code

Project entity identification code

Code	Identification Code
1	Government agencies(Direct project)
2	Other government agencies
3	Project operator(LH)
4	Project entity
5	Private participants

[Appendix 6] Construction stage code

Construction stage code

CODE	Stage Code
G (General)	Ordering
E (Engineering)	Design
C (Construction)	Construction
P (Procurement)	Purchasing
S (Start up)	Commissioning