A Study on effective Design Review of Urban MAGLEV Program case

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Abstract. To reduce the risk of failure in a project of development of complex system, clear definition and verification of system requirements (SR) are very important. It is known that around 50% of project failures are originated to the failure of SR. Therefore, SR should be verified by reviewing design in each development stages. To perform the design reviews (DRs) effectively, the verification concept for the SR should be established in the view of system integration and adequate tools or templates for DR should be prepared. In this paper, a template for effective DR on large complex system is suggested, with references to the Urban MAGLEV Development Program in Korea.

Introduction

Urban MAGLEV program is a kind of complex system. Because of their size, complexity and uniqueness, large projects and their processes are difficult to manage. To develop complex system effectively, consistent application of process in which other person or team having different idea can be participated is required.

The report of the Standish Group suggests that failures of requirement management are major reason of the project failure. Insufficient clear definition and verification activities on the requirements which are most important part of the project result in additional cost and schedule delay. Then the handbook published by INCOSE recommends to review design on each development stage for evaluation of progress status. In system engineering, verification of each requirement in each development stage by comparison of requirements. Also requirement for management tools for verification is increasing in line with development of internet and computer. For effective verification, not only developments of suitable tools to verification concept, but also setting up verification concept to use available tools properly are required.

In this paper, a template for effective design review on Urban MAGLEV Program case of which requirements are verified by effective design review is suggested.

Design review concept

The design review aims to make required activities under the job description and restrictions transparent and to evaluate design output for technical feasibility and conformity with standard specifications, and to verify conformity and feasibility of every technical documents and to make

preparations for forwarding next stage.

The handbook published by INCOSE recommends reviewing system properly in each development stage.

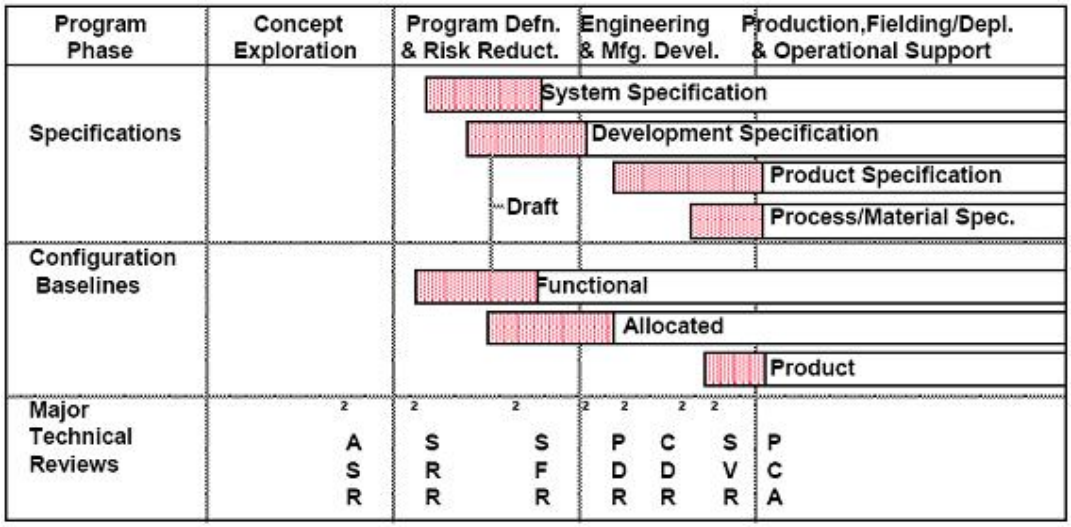


Figure.1 Review schedule of typical requirements and design (INCOSE, Systems Engineering Handbook (Ver. 2a), International Council On Systems Engineering, 2000)

Even though individual schedule and numbers of project review can be varied by size and schedule, but typical case shows in Figure.1. Since requirements analysis of the system is carried out mainly at initial stage of the project, accordingly design review shall be carried out from the start of concept design. Since design process of most projects are composed of preliminary design and critical design, design review also composed of preliminary design review(PDR) and critical design review(CDR).

PDR evaluate progress, technical adaptableness and risks of technology, cost, schedule of selected design approach and review performance and interchangeableness of component requirements. CDR determines whether or not critical design of components meets with requirements and performance of development specifications writings. Also, interchangeableness between components and whole system is confirmed and risks of technology, cost, and schedule are evaluated.

Execution case of Design Review

Design review was introduced to Missile development and Apollo project of USA during 1950~60s at first. Later product liability initiated from defect cars became public problems, it was introduced to private sector to raise reliability of products. Execution cases of CDR are as follows.

(1) Actual presentation of X-15A ultrasonic program

In demonstrator CDR of X-15A Wave-rider Scram-jet Engine of the Boing company, the Government and industrial people review feasibility of design, assembly, integration and flying test plan of flying objects.

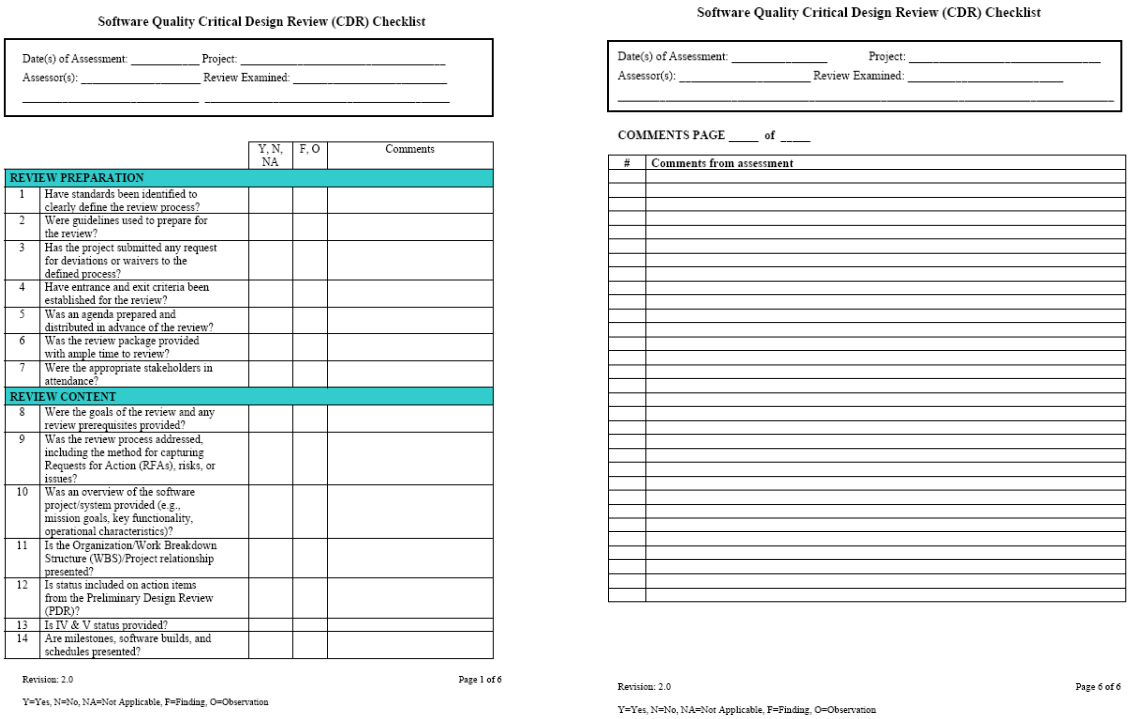
(2) Korean Helicopter Program (KHP)

Its goal is to enter service from 2012, and execution of PDR at the stage of preliminary design

finalizing exterior shape, and execution of CDR at the stage of critical design preparing all design drawings for actual production of helicopters are planned for KHP development schedule.

Limitation of Design Review

Recently most trade items between industrialized countries are highly value-added complex products or systems produced by complicated process. Existent design review is executed usually by simple checklist like Figure.2, which have a little limitation on applying actu ally to large complex system like this program and hence to be improved. Problems generated by executing design review with simple checklist is as follows.



Software Quality Critical Design Review (CDR) Checklist

Date(s) of Assessment: _____ Project: _____
Assessor(s): _____ Review Examined: _____
_____ _____

		Y, N, NA	F, O	Comments
REVIEW PREPARATION				
1	Have standards been identified to clearly define the review process?			
2	Were guidelines used to prepare for the review?			
3	Has the project submitted any request for deviations or waivers to the defined process?			
4	Have entrance and exit criteria been established for the review?			
5	Was an agenda prepared and distributed in advance of the review?			
6	Was the review package provided with ample time to review?			
7	Were the appropriate stakeholders in attendance?			
REVIEW CONTENT				
8	Were the goals of the review and any review prerequisites provided?			
9	Was the review process addressed, including the method for capturing Requests for Action (RFAs), risks, or issues?			
10	Was an overview of the software project/system provided (e.g., mission goals, key functionality, operational characteristics)?			
11	Is the Organization/Work Breakdown Structure (WBS)/Project relationship presented?			
12	Is status included on action items from the Preliminary Design Review (PDR)?			
13	Is IV & V status provided?			
14	Are milestones, software builds, and schedules presented?			

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Y=Yes, N=No, NA=Not Applicable, F=Finding, O=Observation

Software Quality Critical Design Review (CDR) Checklist

Date(s) of Assessment: _____ Project: _____
Assessor(s): _____ Review Examined: _____
_____

COMMENTS PAGE ____ of ____

#	Comments from assessment

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Y=Yes, N=No, NA=Not Applicable, F=Finding, O=Observation

Figure.2 General design review template

At first, MAGLEV system is a large complex system in which vehicle, signal & train control, communication, railway, power and other comprehensive technologies are interlinked. When each sector has plenty contents, requirements could not easily secure verification requirements and traceability to make usability of execution of examination/evaluation lower. Therefore a template which may secure traceability between requirements, design output, basic specifications, and verification requirements is requested. That template may decide concept design of whole system and basic specifications of component system and help to draw and manage mutual interface factors to be generated during design, production process. Urban MAGLEV program is composed of vehicle system and other six systems.

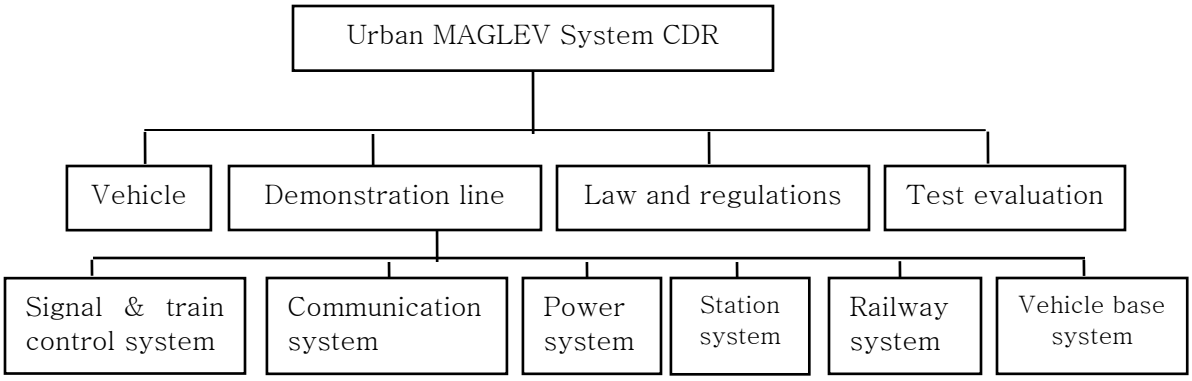

Figure.3 Hierarchical structure of Urban MAGLEV Program system

Secondly, a range of organizations are involved in urban MAGLEV program not only for development of operational MAGLEV system, but for preparing required legislations and a regime for utilizing MAGLEV, establishing suitable RAMS structure to MAGLEV, and executing test and evaluation of whole system. Accordingly all requirements should be managed simultaneously from the diversified view points of designer, legislations and regime, RAMS, test and evaluation, and as such system engineer should manage comprehensively. Existent simple checklist cannot easily manage review opinions comprehensively from such diversified viewpoints. Also drawing review opinions with same tone for each sector is limited. Hence a template with which consistent quality of diversified viewpoints of all stakeholders inside or outside of the project can be obtained and observed at a glance is required.

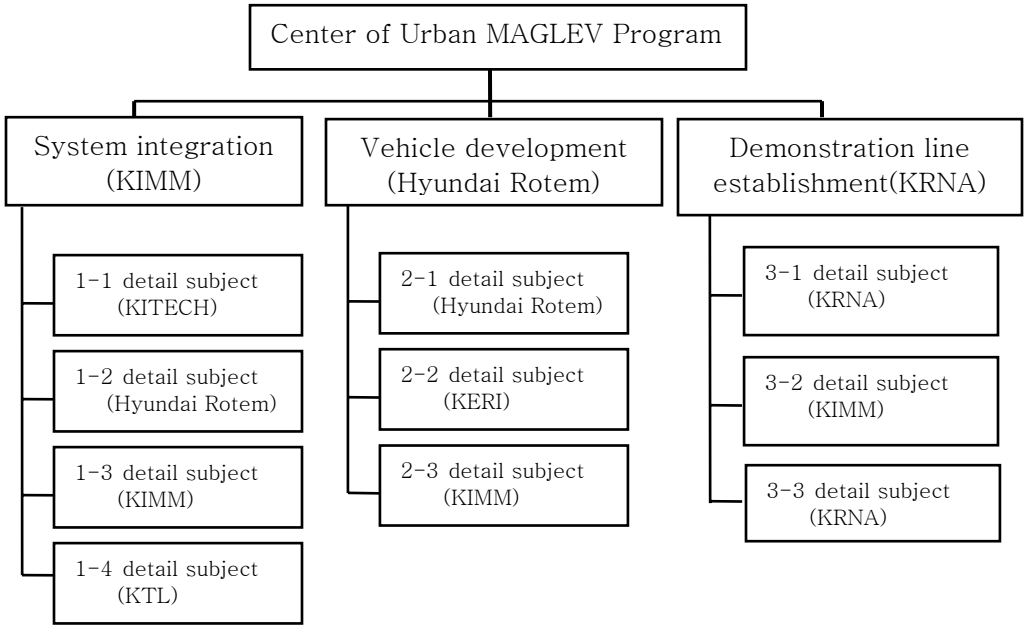

Figure.4 Organization chart of project execution

Concept and configuration of this template

Design review template of urban MAGLEV program is prepared on following viewpoints. Firstly, whether or not all requirements prepared before design review is implemented to the design properly should be confirmed. In other words, all requirements shall be verified by corresponding to related specifications. If there are no corresponding specifications to requirements, design shall be induced to meet all requirements by reviewing design implementation. Secondly, it should be a springboard to define verification method of all specifications and to confirm whether it is implemented to test procedure sheet. Verification method with person in charge of all specifications items shall be confirmed. Also, it can review whether verification requirements are implemented to this test procedure sheet to make adjustment.

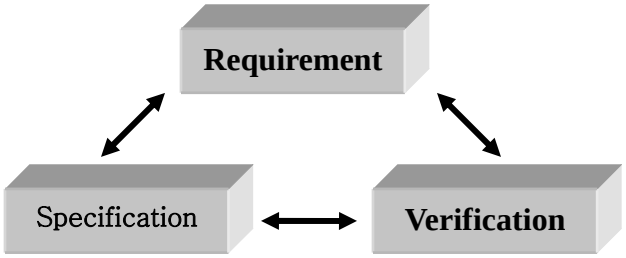

Figure.5 Basic concept of this template

This template helps to collect requirements precisely without fail, and to make easy to secure traceability. This template is prepared by three fields, i.e., requirement field with requirements of design, specification field in which designed specification according to requirements, verification field for verifying feasibility of specifications.

- Requirement field
  - Requirements to be implemented to design by each system
- Specification field
  - Confirm whether kinds of studies and design output related to each requirement are implemented.
  - Arrangement of studies and design output under way in each subject of the team
- Verification field
  - Define handling subject (who) on related specifications and verification method (how)

Table.1 Design review template

Requirement	**Specification**			**Verification**			
Sub system requirement	Law	System specification	Design content	Responsibility	Method	Test item	Proof

CDR execution summary of urban MAGLEV program

Urban MAGLEV program is the project entering into service of large-scale national research development result to install demonstration line for six years from 2006 year to 2012 year. Because that this project is proceeding with procurement and technology development simultaneously, it cannot be executed by specifications defined in one sector one-sidedly but proceeded by organic design and adjustment. This project is composed of three core subjects of system integration, vehicle development, and establishment of demonstration line and under which detail subjects and participating companies are placed. This template of this paper is prepared to execute CDR effectively in the final stage of execution design.

In system integration subject, requirements, which are core of the CDR, are analysed and this template is prepared for effective execution. CDR execution guideline by using this template to make easy communication with other subjects is furnished. Also, execution of vehicle development subject and demonstration line establishment subject is reviewed and integrated. Design results of vehicle development subject and demonstration line establishment subject were prepared to meet feasibility of requirements, which are objective of CDR.

Requirement field.

This is most important sector of this template to draw easily verification requirements and to manage easily through system requirements. In CDR for Urban MAGLEV program requirements, highest goal of the system based on background and effect of project propulsion to system Level 2 were prepared. Requirements drawn from analysing requirements of various stakeholders and operation concept and its feasibility were secured through expert's council and public hearings. System requirements documents of Urban MAGLEV program to enter service have hierarchal and parallel traceability between each system. Requirements for levitation system of the vehicle system were prepared in the table.

Table 2. Preparation example of requirements

Requirement		
Serial numbers	**Requirement name**	**Requirement content**
Tr.R.5	Levitation system	Levitating force (vertical direction) and guide force (horizontal direction) can be generated in vehicle.

Specification field.

Specification column among design review template fields suggested in this study is to confirm if requirements are implemented properly to design. Specification column is an item basically to which design of system hardware and software is implemented. However not even design but propelling job by the project may be included. For example, in urban MAGLEV program, besides facilities/equipments related to MAGLEV, legislation development to be applied to commercialisation and operation of MAGLEV henceforth is included in project mission. How requirements of the project are implemented to developed legislations and a regime till design review should be confirmed together during design review process. Thus 'Law' column is added to specification field among design review template of this project. Also

in this project, subject for tracing and managing specifications of whole project exists to manage system specifications writing, 'system specification' column is added to specification field. Finally 'Design content' column for arranging design output in vehicle and demonstration line sector can be found.

Table.3 Specification field template

Specification		
Law	**System specification**	**Design content**

Urban MAGLEV system is brand new system having no precedent in domestic area, governing legislations did not exist. Currently in this project, urban magnetic levitation railroad construction rule and safety rule for Urban MAGLEV are prepared to be law. Specified contents for MAGLEV system are implemented furthermore to existent railroad law. Thus, a template to secure mutual traceability between drawn requirement and law was prepared. Through this, feasibilities of both requirement and law can be secured.

Table 4. Preparation example of law draft

Specification		
Law	**System specification**	**Design content**
Safety Standard Article 53/ Clauses 1 &, 2 of Article 54/ Article 55 Article 53(levitation.guide system) ① Enough levitation and guide forces can be exerted to guarantee safe drive of the train. ② Change of air gap due to levitation and guide systems shall meet each number of following standard. 1. Even in curved railroad with minimum radius and maximum slope, safe drive can be guaranteed. 2. Stability of train during drive shall be maintained. ③ Enough performance of levitation, guide systems can be exerted even in heated by drive.		

Standard is required in development and production of MAGLEV system. More than standard specifications and writings prepared by producers, specifications writings to integrate every system are required. During CDR of Urban MAGLEV program, specification standard of subsystem level is prepared. Part of levitation system specifications of vehicle system specifications writings is prepared in the table.

Table 5. Preparation example of specification

Specification		
Law	**System specification**	**Design contents**
	5.4 Levitation system 5.4.1 General 1) Structure is designed that required power(electric current) quantity is calculated according to load condition of vehicle, actual air gap and set supply to be loaded to power converter, in which converted electric power is supplied to electro-magnet. 2) Levitation system is composed of computation and power conversion system (Magnet Driver), Gap Sensor, Acceleration Sensor and electro-magnet and others. 3) Levitation force generated during drive shall be distributed fully on the track to secure drive safety from concentrated load.	

Requirements shall be implemented to design enough to meet with legislations and specifications writings of system, and to have mutual traceability. Actual design matters are presented. Design contents of levitation system of vehicle system are presented in the Table.

Table 6. Preparing example of design contents

Specification		
Law	**System specification**	**Design content**
		* Levitation system - Equipped with Long Pole electro-magnet to reduce Drag Force and weight - System Redundancy concept is implemented partially. - Number of electro-magnet: 32 set/vehicle - Bogie mechanism design for stable drive in curve and slope railway.

Verification field.

System verification field is composed of contents related to verification of specifications. The template is prepared to trace system requirements corresponded respectively to verification requirements. System verification field is classified by responsible organization for verification, verification method, test/evaluation items, and ground data. This traceability means that each requirement shall be verified by test and evaluation plan, verification requirements is the item to be verified.

Because that this project is large-scale program in which a range of organization is participated, lots of interfaces are required. In the Responsible Organization for Verification item, subject number and name of the subject responsible for design and verification of

implementation of requirements shall be filled in.

Verification method of requirements shall be described in Method item. Usually four methods of following Table would be used for verification.

Table 7. Verification Method

Method	Content
Analysis	Verification method to confirm that related technical analysis or modelling, simulation and others satisfy specifications.
Demonstration	Verification method to confirm that related specifications are satisfied by software test bed, training simulator, mock-up and others in case that numerable opportunity cost is expected to test by produced target system or actual components.
Visual Inspection	Verification method to find any defect of test body by observing material, product or structure (test body) directly or indirectly
Test	Verification method to confirm that required performance value or function would be revealed under given boundary condition by operating mockup or actual equipment.

In above case, because that bridge deflection limit is reviewed in the design stage by analysis initially, and deflection would be confirmed by field measuring (test) after production verification method is prepared by analysis and test.

Test items are prepared to make confirmation of requirements. Those may be used as the base of the Test Evaluation Management Plan. Required test procedure, test equipment and facilities, test organization and other detailed contents will be executed in corresponding subject. In this subject, requirements can be verified with these test evaluation items and traceability.

In Proof items, ground documents are prepared to confirm verification result. Drawing, design report, analysis report, review report and others may be objectives. Following Table is prepared example of verification sector for levitation system of vehicle system.

Table 8. Preparing example of verification sector

Verification			
Responsibility	**Method**	**Test item**	**Proof**
2-1 Detail 2-2 Cooperation	Analysis Test	Performance test of train(Start test in the slope)	Result report of simulation Design report

Table 9. Preparing example of design review template of Urban MAGLEV program

Requirement			Specification			Verification				Risk(영향성)	현황	비 고
일련번호	요구사항 제목	요구사항 내용	법안	규격서	설계 내용	담당과제	검증방법	시험평가항목	근거자료			
Tr.R.5.	부상장치	차량에 부상력(수직방향)과 안내력(수평방향)을 발생시킬 수 있어야 한다.	안전기준 제53조/제54조 1항,2항/제55조 제53조(부상, 안내 장치) ① 열차의 안전한 운행이 가능하도록 충분한 부상력과 안내력을 발휘할 수 있어야 한다. ② 부상, 안내 장치에 의한 공극의 변화는 다음 각 호의 기준을 만족하여야 한다. 1. 최소 곡선반경 및 최대 기울기의 경사선로에서도 안전한 주행이 가능하여야 한다. 2. 운행 중 열차의 안정성을 유지할 수 있어야 한다.	5.4 부상장치 5.4.1 일반 1) 차량의 허중조건, 전자석과 궤도 레일 사이의 설계 공극(Gap) 및 설정된 공극에 따라 필요한 힘(전류)의 양을 계산하여 전력변환장치에 인가하고, 전력변환장치는 전력을 변환하여, 전자석에 공급하는 구조로 설계한다. 2) 부상장치는 연산 및 전력변환장치(Magnet Driver), Gap Sensor, 가속도 Sensor 및 전자석(Magnet) 등으로 구성된다. 3) 주행 중에 발생하는 차량의 부상력은 궤도에 충분히 분산되도록 하며, 집중하중으로부터 주행안전을 확보해야 한다.	- Drag Force를 줄이고 경량화를 위해 Long Ploe 전자석 적용 - 시스템 Redundancy 개념 일부 적용 - 전자석 수량 : 32대/량 -곡선주행 및 경사선로 주행의 안정성을 위한 대차 메커니즘 설계(조향기능을 갖는 대차설계)	2-1세부 2-2세부 2-3세부	분석 시연 유연검사 시험	도시형 자기부상열차 차량성능시험에 관한 기준(안) <부상제어장치 시험> 자기부상열차 차량에 장착되는 부상안내제어기 또는 마그넷트 드라이브(전자석 전력공급장치-량행 쵸퍼)의 성능을 확	분기 및 연차보고서 참조	일정 : 0.1 비용 : 0.1 품질(성능) :0.3		
Tr.R.6.	추진장치	추진장치는 차량이 주행 안전성과 승차감을 저해하지 않고 가감속할 수 있도록 하여야 한다.	안전기준 제57조 제57조(추진장치) ① 추진장치는 주행 안전성을 저해하지 않고 가감속 할 수 있어야 한다. ② 정상 운행 중 부상공극의 변화가 발생되어도 추진을 제어할 수 있어야 한다. ③ 추진장치는 운행에 의해 가열되어도 충분한 성능을 발휘할 수 있어야 한다.	5.5 추진장치 5.5.1 일반 1) 추진장치는 각 차량당1대의 인버터와 8대의 선형 유도전동기로 구성하며, 차량의 역행 및 전기제동을 수행한다. 2) 소형, 경량화 설계에 역점을 두며, 차량의 신뢰성, 보수성 및 에너지 효율의 향상 등 본 시스템이 갖는 특성을 최대한 발휘할 수 있도록 한다.	- 선형유도전동기(LIM)의 수직력 최소화를 위한 제어 알고리즘 적용 - 고조파에 의한 선형유도전동기(LIM)에서의 자기음 최소화 - 방열 및 보수성 고려한 장치 설계 - LIM 수량 : 8대/량	2-1세부 2-1형동	분석 시연 유연검사 시험	도시형 자기부상열차 차량성능시험에 관한 기준(안) <추진제어장치 시험> 자기부상열차 차량의 추진제어시스템을 구성하는 추진제	- 시뮬레이션 결과보고서 - 설계 보고서 - FEM 해석 결과보고서	일정 : 0.1 비용 : 0.1 품질(성능) : 0.3		
Tr.R.25.	불연 또는 난연재 사용	자기부상열차 시스템은 '도시철도차량안전기준에관한규칙' 제12조 2항 2호 불연재질에 관한 조항을 준수해야 한다.	안전기준 제12조 제12조(화재 예방을 위한 기준) ① 차량의 차체 및 실내 설비는 다음 각 호의 어느 하나에 해당하는 불에 타지 아니하는 재료(이하 "불연재료"라 한다)를 사용하여야 한다. 1. 알, 구리, 알루미늄, 스테인레스 등	5.2 실내내장 실내내장에 사용하는 모든 재료는 도시형 자기부상열차 안전기준에 관한 규칙에서 규정한 재료를 사용하여야 한다.	-내장판: 난연 FRP 사용 (화재안전기준만족) -단열재: 불연 신소재사용(65-08 및 리플렉쉴) -의자 : 난연 모케트 사용 (100% WOOL) -바닥재 : 난연고무 바닥재 사용 -설비이 : 난연 실리콘고무 사용	2-1차량개발	화재시험	**시험에서규정한분기항목** **-화염전파** **-산소지수** **-연기발도** **-독성지수**	철도안전법에 따른 화재시험 성적서	일정 :0.1 비용 :0.1 품질(성능) :0.1		
Tr.R.29.	표지	안전성에 관한된 부분에는 "고전압", "위험" 등의 식별 표시를 해야 한다.	안전기준 제15조 1항/제16조 2항,3항/제18조 1항,3항/제20조 4항,7항,8항/제24조 1항,4항/제25조 1항/제26조 1항/제27조 1항/제28조 2항,6항/제30조 1항/제36조 1항1호 제15조(표찰) ①	5.2.15 전기기기 배치에 대한 안전기준 2) 안전상 필요한 위치에는 "고전압" 또는 "위험" 표지를 하여야 한다.	규정에따라 필요한 모든 표지 설치토록 설계	2-1차량개발	도면에따라감중 KSA0901 KSA3501 KSA3801	KS규정에따라 평가	도면 성적서	일정 :0.1 비용 :0.1 품질(성능) :0.1		

Conclusion

In this paper, a template is prepared for design review of Urban MAGLEV program. Existent design review is executed usually by simple checklists, which have a limitation in applying actually to large complex system like this program. Hence a template with which consistent quality of diversified viewpoints of all stakeholders inside or outside of the project can be obtained and observed at a glance is required.

By this design review template of Urban MAGLEV program, whether all requirements are implemented to design properly can be confirmed, and verification method of all specifications can be defined and also a springboard was made to confirm whether verification requirements are implemented to this test procedure sheet.

This template is composed of three fields, i.e., in requirement field, requirements to be implemented to design per each system is prepared, in specification field, whether various studies and design output are implemented to each requirement can be confirmed and in verification field, corresponding subject to related specifications and verification methods are defined.

Suggested template is expected to be used effectively in large scale research development projects like this program.

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