A Study on the Provision of National R&D Information in LOD (Linked Open Data) Format

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Abstract

Objectives: To establish a system which provides the NTIS (National Science and Technology Information Service)-owned information in a LOD (Linked Open Data) format for the purpose of opening national R&D information to realize 'Government 3.0'.

Methods/Statistical Analysis: The NTIS ontology has been designed using the CERIF (Common European Research Information Format) ontology which efficiently manages research information and BIBO (Bibliographic Ontology) targeted to describe literature data in a library with the RDF (Resource Description Framework). To decide a scope to provide the NTIS information in LOD format and convert it into triple data, R2RML is used. In addition, Pubby is adopted for an interface between the server and application while a triple store uses OntoBase2.0.

Findings: Among a total of 389 national R&D information items provided by the NTIS, those except for personal information, secret and national defense and management items were set to be provided in LOD format. After analyzing 30 tables, the matters to be referred to during modeling were derived. In addition, ontology was designed by deriving item-concept or inter-concept relationships. To convert NTIS information into RDF, R2RML was used and the extracted triple data are stored in a triplestore. Users are able to get access to LOD data, using a SPARQL endpoint.

Improvements/Applications: It is able to provide a lot of related information through connection with diverse LODs after opening national R&D information in LOD format. Then, this information would be available as base data in science and technology.

Keywords: BIBO, CERIF, Linked Open Data (LOD), National R&D Information, NTIS, Ontology Modeling

1. Introduction

'Government 3.0' is a new paradigm for government operation to deliver customized public services and generate new jobs in a creative manner by opening and sharing government-owned data to the public and encouraging communication and collaboration between government departments. To reflect these trends, the NTIS has expanded the opening of national R&D information in diverse manners such as cloud analysis services and open-API to realize 'Government 3.0' in science and technology.

As a part of the methods to open national R&D information, the NTIS has operated the NTIS LOD services through which the NTIS-owned data are provided in LOD format. This study attempted to find methods to provide NTIS LOD services such as analysis of national R&D data, ontology design, inter-linking with external LOD and development of LOD platform.
2. Ontology Analysis

2.1 CERIF Ontology

The CERIF is a standard format developed to efficiently manage and share research information among European countries. It was designed for the purpose of managing and sharing the information needed for diverse research activities in an efficient fashion. It was developed by the European Commission (EC) from 1987 to 1990 and from 1997 to 1999. Since 2000, its management and supervision were transferred to euroCRIS.

The CERIF covers overall academic research activities in which components interact with each other, not focusing on single information such as research project or outcome. It suggests a model for the academic research information system. As a data model for the European Research Gateway On-line (ERGO) services, furthermore, it is applied to each country’s Current Research Information System (CRIS) and has provided integrated services.

The CERIF ontology is used after being converted into the one based on the entity defined in the CERIF data model. It provides linked data after converting the data in the RDB into RDF through a D2r server.

Figure 1. CERIF 1.3 entities and their relationships (abstract view).

As shown in Figure 1, the CERIF’s entity is mostly expressed in class and inter-entity relationship is defined and expressed in property. To meet the requirements such as stability, usability and simplicity, the CERIF entity is classified into five categories: Core entity, 2nd-level entity, linked entity, language-dependent entity and classification entity. To express inter-entity relationship, the CERIF has created ‘relationship’ and ‘classification’ classes and used them as a medium to connect two entities.

2.2 BIBO Ontology

The BIBO is an ontology which described literature information in RDF format. It is used as a method to state the bibliographic data in a library in RDF. The use of RDF has the following advantages: Effective scalable mechanism, easy harmony between the BIBO-based expressions and those expressed in different RDF vocabulary. The website of Chronicling America run by the Library of Congress in the U.S. uses the BIBO and provides services. Since the version 1.0 dated November 2008, ‘1.3’ announced in November 2009 is the latest version. The BIBO provides examples to express paper-journal, paper-proceeding and inter-conference relationships as shown in Figure 2. In general, they are defined by recycling DC and events.

Figure 2. BIBO: Article-journal example.

3. Scope of the NTIS-owned Information to be converted into LOD Format

3.1 Overview of the NTIS

The NTIS is a national R&D portal service which is provided to the general public as well as to government bureaus by connecting national R&D-related projects, research outcome, researchers and research equipment and facilities in real time as illustrated in Figure 3. This service is widely used in supporting researchers’ R&D activities and government duties such as policy making and budgeting.
As of February 2016, the NTIS provides national R&D information as follows: 540,000 items of project information, 160,000 items of research information and 3.97 million items of research outcome data. These data are provided through web services.

3.2 Scope of the NTIS-owned Information to be converted into LOD Format

Among the national R&D information provided by the NTIS, the criteria aimed to screen and exclude the data to be converted into LOD were defined as stated in Table 1. Among a total of 389 items owned by the NTIS, the data which met the said criteria were chosen. Then, the vocabularies good for these data were designed. Standardized vocabularies were primarily used for interlinking with external LOD at vocabulary design. When such standardized ones were unavailable, NTIS vocabularies were created.

Table 1. Screening and exclusion criteria for scope of NTIS-owned information

| Category           | Description                                                                 |
|--------------------|-----------------------------------------------------------------------------|
| Screening Criteria | All data provided to the NTIS users                                         |
|                    | Data to be checked through the web services of the NTIS                     |
|                    | Data needed to provide LOD services                                         |
| Exclusion Criteria | Data which cannot be checked through the web services of the NTIS (non-disclosed, secret and national security-related information, etc.) |
|                    | Data with low efficiency and fidelity                                        |

4. NTIS LOD Platform Design

4.1 Lifecycle of the NTIS

As shown in Figure 4, the life cycle of the NTIS LOD consists of the following seven steps which meet the characteristics of the NTIS based on the W3C (5-phase government linked data lifecycle) in Figure 5: Extract, Model, Generate, Store, Publish, Interlinking and Exploit. Each step can be explained as follows:

- **Extract**: A step to extract the data which would be established in LOD format and set a scope of provision.
- **Model**: A step to design URI, vocabulary and ontology relationship to provide LOD.
- **Generate**: A step to convert the NTIS data in RDB into RDF.
- **Store**: A step to store the RDF data in a triplestore.
- **Publish**: A step to issue the data in a triplestore through web.
- **Interlinking**: A step to improve the quality of the LOD data through interlinking with external data.
- **Exploit**: A step to utilize the data through the utilization of other services.
4.2 NTIS LOD Ontology Modeling

4.2.1 NTIS Data Analysis
The NTIS-owned national R&D information consists of a total of 389 items in 30 tables such as project, outcome, manpower and equipment. The results of the analysis on all data are stated in Table 2. Table 2 states the matters to be referred to during modeling based on the data. For example, even same paper data need to be classified into if they are project-induced papers or those created by researchers.

4.2.2 Concept by Item
After analyzing the tables in which national R&D information is stored, each concept by item was derived as described in Table 3. In national R&D information, the base fundamental information is project data. Based on the project, the following information was derived as concept: Project-included programs, assistance researchers participating in the project and project-induced results. Furthermore, researchers’ performances, qualification, academic degree and educational background and information on research equipment and facilities were obtained.

As stated in Table 4, a total of 54 inter-concept relationships were derived based on the following concepts: Projects, institutes, researchers and papers. Table 4 reveals some of them as examples. For example, for the relationship between the project and institute, diverse relations such as ‘managed’ and ‘performed’ were derived.

Table 2. Matters to be referred to at NTIS modeling

| Data                                                                 | Matters to be Referred to for Modeling                                                                 |
|----------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| The NTIS’ standard items consist of 40 items in five categories.     | Five categories divide the 389 standard items. They reflect a concept of entity.                       |
| Research outcome is divided into the result of a project and result of personal performances. | Aside from a concept on research outcome, a concept of performance is created. As the sub performance concept, the result of the project and concept of personal performances are created for inter-classification. |
| There are a lot of items which are managed by code. The following codes are meaningful if opened to the public: Region code, region type (materials and equipment), 6T, NTRM, science & technology standard classification code and software type code. | Region code, region type (materials and equipment), 6T, NTRM, science and technology standard classification code and software type code are configured in instance to be available outside. |
| Among a total of 389 items, ‘title’ is included while ‘institute code’ is not available in the institute. | An instance on the institute is created using the institute code given by the NTIS.                     |
| In ‘project information,’ institute codes which individually respond to institute name, research management institute and research institute are found. | An instance on the institute is created using the institute code given by the NTIS.                     |
| Change in the assistant researcher’s academic major, department, academic degree, participation rate, role and participation period at the time of participation in the project | It is needed to design a model which can express information at the time of participation in the project by introducing a concept which describes relationship between the researcher and project. |
| Even though an institute title exists in the bio-resource, life resource, compound and research report, institute codes are all stated as ‘null.’ | The research outcome-related institute titles are expressed as ‘literal.’                                |
| A project is divided into the assigned project and co-research project. Then, the co-research project is classified into domestic and international co-research projects. | Specific, assigned and co-research projects are all within the concept of ‘project.’ Therefore, a concept is derived under the sub of the project. The specific project is created as a concept of the main project of the NTIS. Then, the assigned project and co-research project which have related with the specific project are reflected on the model. |
| The outcome itself is not managed so that the sources of the journal aren’t taken care of. | The journal-paper relationship is stated in simple literal.                                           |
In case of patents and papers, the project’s contribution rate exists. Even same research outcome is managed under different outcome ID.

Since the research outcome is managed under different outcome ID, it can be reflected on a model with binary relation only.

In terms of the volume number, data are not refined.

The relationship between the journal and volume number is stated in simple literal.

The following projects do not create a triple: The projects of national defense or national defense secret, security projects, projects which meet the conditions of the date of secret cancelled, virtual projects and those with ‘A’ in job type.

The conversion rules would be created not to create the data which the conditions for the creation of a triple.

Outcome information should be those who can be opened to the public.

The conversion rules would be created not to create the data which the conditions for the creation of a triple.

The data form would be ‘YYYY-MM-DDThh:mm:ss.’

The data would be in either ‘xsd:date’ or ‘xsd:dateTime’ format depending on actual data.

In case of an institute, a pair of institute code and institute name exists. However, the institute names are separately managed.

Unless it is able to acquire the institute name, a triple would be created with the standard institute name.

In case of the staff participating in the project, email addresses are kept but unfiltered.

Even unfiltered data are stated in literal.

In terms of the staff participating in the project, inactive ID is being converted into scientist registration number. However, many inactive IDs are still found.

The scientist registration number is personal information so that it wouldn’t be converted.

In terms of project annual information, it is been uncollected for 4-5 years.

Sanction information and project announcement information are not created as a triple.

### Table 3. Results of the deduction of concepts by item

| Category          | Sub-category                                      | Concept                                      | Additional Concept                                                                 |
|-------------------|---------------------------------------------------|----------------------------------------------|-----------------------------------------------------------------------------------|
| project           | Program information                               | Program information, project                 | Region type, science and technology standard classification, 6T-related technology, main science and technology classification |
|                   | Basic information                                 | Project, institute                           |                                                                                   |
|                   | Assessment addition and deduction information     |                                              |                                                                                   |
|                   | Research expense information                      | Project                                      |                                                                                   |
|                   | Assigned project / co-research                    | Project, assigned project, domestic co-research project, international co-research project, institute |                                                                                   |
|                   | Assistant researcher information                  | researcher, project, institute               |                                                                                   |
|                   | Sanction information                              | Sanction information, project                |                                                                                   |
|                   | R&D announcement                                  | R&D announcement, project                    |                                                                                   |
|                   | Annual information                                | Annual information, project                  |                                                                                   |
| Research outcome | Training support | Project, training support |
|------------------|------------------|--------------------------|
| Technology trade | Technology trade, project, institute |
| Paper (publication outcome) | Paper, project, researcher | Paper type |
| Commercialization | Commercialization, project |
| Intellectual property right | Patent, project | Patent type |
| Manpower cultivation (results) | Manpower cultivation, project, researcher |
| Bio-resources (outcome) | Bio-resources, project |
| Bio-information (outcome) | Bio-information, project |
| New variety (outcome) | New variety, project |
| Compound (outcome) | Compound, project |
| Software (outcome) | Software, project |
| Research report (outcome) | Research report, project |
| Technology summary | Technology summary, project |

| Participating manpower | Career data | Career data, researcher |
|------------------------|-------------|-------------------------|
| Basic information | Work data, researcher |
| Paper results | Paper results, researcher | Personal result |
| Certification | Certification, researcher |
| Institute | Institute, researcher |
| Intellectual property rights | Patent results, researcher | Personal result |
| Education | Academic paper, researcher |
| Educational background | Educational background, researcher |

| Assessor | Institute data | Institute data, assessor |
|----------|----------------|-------------------------|
| Book results | Book, assessor | Personal result |
| Reward | Reward, assessor | Personal result |

| Research equipment and facilities | General equipment and facilities | Research equipment and facilities |
|----------------------------------|----------------------------------|----------------------------------|
| Equipment and facility acquisition information | Research equipment and facilities, project |
| Utilization of equipment and facilities | Research equipment and facilities |
| Management of equipment and facilities | Research equipment and facilities |
| Information on joint use of equipment and facilities | Utilization information, research equipment and facilities |
| Equipment & facility connecting information | Connecting information, research equipment and facilities |

### 4.2.3 Design of NTIS Ontology

The NTIS ontology was designed by referring to the CERIF ontology and BIBO. In addition, the relationship concept of the CERIF and the paper-journal relationship of the BIBO were adopted. In addition, Dublin Core (DC) and FOAF ontology were reused. If necessary, vocabularies were created.

The URI system on the class and property of the NTIS ontology is `http://lod.ntis.go.kr/ontology/RESROUCE_NAME`. Prefix is `ntis` while the namespace URI is `http://lod.ntis.go.kr/ontology`. In terms of the examples of URI on data (instances), ‘project’ is `http://lod.ntis.go.kr/resource/PJT1665005412` while ‘paper’ is `http://lod.ntis.go.kr/resource/JNL-2007-00100331359`. 

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| NO | Concept 1          | Concept 2                                       | Connection Relationship |
|----|--------------------|-------------------------------------------------|-------------------------|
| 1  | Project            | Program information                             | Budget program          |
| 2  | Program information| Project                                         | Project                 |
| 3  | Project            | Project                                         | Previous project        |
| 4  | Project            | Project                                         | Next project            |
| 5  | Project            | Region type                                     | Classified              |
| 6  | Project            | Science and technology standard classification  | Classified              |
| 7  | Project            | Institute                                       | Managed                 |
| 8  | Project            | Institute                                       | Performed               |
| 9  | Researcher         | Institute                                       | Worked                  |
| 10 | Project            | Paper                                           | Research outcome        |

Table 4. Inter-concept connection relationship

Based on the concepts derived in the section 4.2.2 above, class and property were designed. Total class was classified into concept, class and upper class as stated in Table 5. In Table 6, project data were only listed among the properties on the NTIS ontology.

The structure of the NTIS class is divided into BaseEntity, SubEntity and ResultEntity and key national R&D information items were composed under ‘BaseEntity’ and created into Project, Organization, BudgetProgram, Researcher, Assessor and Facility and Equipment. The structure is shown in Figure 6. The arrows refer to hierarchical relationship among classes while the dotted lines represent the equal relationship. The ‘ntis:Relationship’ in the middle of the Figure 6 is explained in Figure 7. This figure defines the relationship among project, manpower and paper with ‘ntis:linkTo’ and ‘relatedTo’ properties.

The Figure 8 specifically represents class-property relationship on the ‘project’ class. Around ‘ntis:Project,’ ‘ntis:ResultEntity’ has ‘ntis:outcome’ property and ‘1:n’ relationship as the outcome from the project. The project-program relationship has ‘ntis:budgetProgram’ property and ‘1:1’ relationship as ‘budget program’. In addition, the project-institute relationship has ‘1:1’ relationship and the following properties: ‘ntis:performedBy’ which refers to ‘institute which performed the project,’ ‘ntis:managedBy’ that is the project-managing institute. Focusing on ‘persons,’ furthermore, it has ‘ntis:linkToPerson’ that is ‘project participant’ and ‘ntis:affiliatedTo’ which represents ‘person affiliated to an institute.’

4.3 Creation of Triple Data and Interlinking
To convert NTIS data into a triple, R2RML is designed and converted into RDF data. For this, a total of 36 triple conversion rules were defined. In project information, five conversion rules were created: 1. Project (detailed) conversion rule, 2. Project (main) conversion rule, 3. Project-outcome conversion rule, 4. Project-relationship conversion rule and 5. Project-science and technology classification conversion rule.

For interlinking with external LOD, the external connection with the NDSL, Korean Intellectual Property Office and national bibliographic database was performed as follows. (Table 7).

4.4 LOD Platform
To develop the ground in which data can be freely used on the web after issuing national R&D information provided by the NTIS in LOD format, the created data are loaded, using the conversion rules expressed in R2RML and triple converter. As shown in Figure 9, the NTIS LOD platform consists of RDF layer, servlet container and application layer. The linked data service plays an interface role between the server and application, using the java web program ‘Pubby’. A triplestore loads and provides the created RDF data, using OntoBase2.0. Then, users are able to get access to the NTIS LOD data, using the SQARQL endpoint.
### Table 5. NTIS ontology class

| Concept | Title | Upper Class | Remark |
|---------|-------|-------------|--------|
| Assessor | ntis:Assessor | ntis:BaseEntity | FOAF vocabulary |
| Program information | ntis:BudgetProgram | ntis:BaseEntity |  |
| Research equipment and facilities | ntis:FacilityAndEquipment | ntis:BaseEntity |  |
| Organization | ntis:Organization | ntis:BaseEntity | FOAF vocabulary |
| Project | ntis:Project | ntis:BaseEntity | FOAF vocabulary |
| Researcher | ntis:Researcher | ntis:BaseEntity | FOAF vocabulary |
| 6T-related technology | ntis:NewTechnology | ntis:Classification |  |
| Main science and technology classification | ntis:NTRM | ntis:Classification |  |
| Paper type | ntis:PaperType | ntis:Classification |  |
| Patent type | ntis:PatentType | ntis:Classification |  |
| Region type | ntis:RegionType | ntis:Classification |  |
| Science and technology standard classification | ntis:STSC | ntis:Classification |  |
| Base entity | ntis:BaseEntity | ntis:Entity |  |
| Result entity | ntis:ResultEntity | ntis:Entity |  |
| Sub entity | ntis:SubEntity | ntis:Entity |  |
| Personal result | ntis:PersonalResult | ntis:Result |  |
| Project result | ntis:ProjectResult | ntis:Result |  |
| Bio-information | ntis:BioInformation | ntis:ResultEntity |  |
| Compound | ntis:Compound | ntis:ResultEntity |  |
| Commercialization | ntis:Industrialization | ntis:ResultEntity |  |
| Manpower cultivation | ntis:ManpowerCultivation | ntis:ResultEntity |  |
| New variety | ntis:NewVariety | ntis:ResultEntity |  |
| Bio-resources | ntis:OrganismResource | ntis:ResultEntity |  |
| Paper | ntis:Paper | ntis:ResultEntity | BIBO vocabulary |
| Patent | ntis:Patent | ntis:ResultEntity | BIBO vocabulary |
| Research report | ntis:ResearchReport | ntis:ResultEntity | BIBO vocabulary |
| Software | ntis:Software | ntis:ResultEntity |  |
| Technology summary | ntis:TechnologyAbstract | ntis:ResultEntity |  |
| Technology trade | ntis:TechnologyTrade | ntis:ResultEntity |  |
| Training support | ntis:TrainingSupport | ntis:ResultEntity |  |
| Annual information | ntis:AnnualInformation | ntis:SubEntity |  |
To publish national R&D information in LOD format, web services which support SPARQL endpoint and browser functions were created. Figure 9 reveals the SPARQL endpoint. If [Start] is pressed after entering SPARQL in this page, the query is delivered to the Pubby. Then, Pubby searches the target triple in OntoBase2.0 and provides it to the users. The results are provided to users in diverse forms such as RDF, JSON, HTML, N-Triples and XML. In addition, they can be freely downloaded.

5. Conclusion

This study investigated how to provide the NTIS-owned information in LOD format as a way to open national R&D information to the public. To provide NTIS LOD data, ontology was created by deriving a scope of the provision, matters to be referred to for modeling and item-concept/inter-concept relationships. Then, a platform was designed and developed. For diverse connectivity, furthermore, interlinking information with other LODs such as NDSL and Korean Intellectual Property Office was developed.

The national R&D-related information such as project, researcher and outcome is basic data which cannot be found elsewhere. It appears that a lot of data would be provided through connection with diverse LODs.

However, there should be further studies on a system in which national R&D information can be published and revised in LOD format as it is created and adjusted in realtime and its issuance for ‘open’ or ‘confidential’ which is applied on a realtime basis according to ‘Data Open Policy’.

6. Acknowledgments

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### Table 6. NTIS project information property list

| Property                                      | Title                                                   | rdfs.domain       | rdfs.range       |
|-----------------------------------------------|---------------------------------------------------------|-------------------|-----------------|
| ntis:abstractOfContent                        | Abstract                                                | ntis:Project      | xsd:string      |
| ntis:abstractOfExpectedEffect                 | Expected effects                                        | ntis:Project      | xsd:string      |
| ntis:abstractOfGoal                           | Goal                                                    | ntis:Project      | xsd:string      |
| ntis:amountOfDirectCostActualStock            | Direct costs (in-kind)                                  | ntis:Project      | xsd:string      |
| ntis:amountOfDirectCostCash                   | Direct costs (cash)                                     | ntis:Project      | xsd:float       |
| ntis:amountOfEtceteraActualStock              | Private R&D expenses (other in-kind)                    | ntis:Project      | xsd:float       |
| ntis:amountOfEtceteraCash                     | Private R&D expenses (other cash)                       | ntis:Project      | xsd:float       |
| ntis:amountOfIndirectCost                     | Indirect costs                                          | ntis:Project      | xsd:float       |
| ntis:amountOfLaborCostActualStock             | Labor costs (in-kind)                                  | ntis:Project      | xsd:float       |
| ntis:amountOfLaborCostCash                    | Labor costs (cash)                                     | ntis:Project      | xsd:float       |
| ntis:amountOfLargeEnterpriseActualStock       | Private R&D expenses (big business, in-kind)            | ntis:Project      | xsd:float       |
| ntis:amountOfLargeEnterpriseCash              | Private R&D expenses (big business, cash)               | ntis:Project      | xsd:float       |
| ntis:amountOfLocalGovernmentActualStock       | Private R&D expenses (local government, in-kind)       | ntis:Project      | xsd:float       |
| ntis:amountOfLocalGovernmentCash              | Private R&D expenses (local government, cash)           | ntis:Project      | xsd:float       |
| ntis:amountOfMaterialCost                     | Material expenses                                       | ntis:Project      | xsd:float       |
| ntis:amountOfMiddleStandingEnterpriseActualStock | Private R&D expenses (mid-standing enterprise, in-kind) | ntis:Project      | xsd:float       |
| ntis:amountOfMiddleStandingEnterpriseCash     | Private R&D expenses (mid-standing enterprise, cash)    | ntis:Project      | xsd:float       |
| ntis:amountOfSmallAndMediumEnterpriseActualStock | Private R&D expenses (small & medium-sized enterprise, in-kind) | ntis:Project      | xsd:float       |
| ntis:amountOfSmallAndMediumEnterpriseCash     | Private R&D expenses (small & medium-sized enterprise, cash) | ntis:Project      | xsd:float       |
| ntis:amountOfUniversityActualStock            | Private R&D expenses (college, in-kind)                 | ntis:Project      | xsd:float       |
| ntis:amountOfUniversityCash                   | Private R&D expenses (college, cash)                    | ntis:Project      | xsd:float       |
| ntis:announcementInformation                  | Announcement information                                | ntis:Project      | ntis:RnDAnnouncement |
| ntis:annualInformation                        | Annual information                                      | ntis:Project      | ntis:AnnualInformation |
| ntis:budgetProgram                             | Budget program                                          | ntis:Project      | ntis:BudgetProgram |
| ntis:project                                  | Project                                                 | ntis:BudgetProgram | ntis:Project   |
| ntis:costOfGovernmentInvestment               | Government investment                                   | ntis:Project      | xsd:float       |
| ntis:countOfAgricultureForestryMajor          | No. of staff who majored in agriculture, forestry and fisheries in college | ntis:Project      | xsd:integer     |
| **ntis:countOfEngineeringMajor** | No. of staff who majored in engineering in college | ntis:Project | xsd:integer |
|-------------------------------|--------------------------------------------------|--------------|-------------|
| **ntis:countOfEtceteraMajor** | No. of staff who majored in other major in college | ntis:Project | xsd:integer |
| **ntis:countOfFemale** | No. of female staff | ntis:Project | xsd:integer |
| **ntis:countOfHumanitiesSociologyMajor** | No. of staff who majored in humanities and social sciences in college | ntis:Project | xsd:integer |
| **ntis:countOfMale** | No. of male staff | ntis:Project | xsd:integer |
| **ntis:countOfMasterDegree** | No. of staff holding master's degree | ntis:Project | xsd:integer |
| **ntis:countOfMedicineHealthMajor** | No. of staff who majored in medicine and health in college | ntis:Project | xsd:integer |
| **ntis:countOfNaturalScienceMajor** | No. of staff who majored in natural science in college | ntis:Project | xsd:integer |
| **ntis:countOfPhDDegree** | No. of staff holding Ph.D. degree | ntis:Project | xsd:integer |
| **ntis:countOfUndergraduate** | No. of staff holding bachelor's or lower degree | ntis:Project | xsd:integer |
| **ntis:dateOfCurrentYearEnd** | Date of current year ended | ntis:Project |             |
| **ntis:dateOfCurrentYearStart** | Date of current year started | ntis:Project |             |
| **ntis:dateOfSecretCancellation** | Date of secrete cancelled | ntis:Project |             |
| **ntis:detailProgram** | Specific program | ntis:Project | xsd:string |
| **ntis:detailProjectClassification** | Features of specific program | ntis:Project | xsd:string |
| **ntis:facility** | Facilities | ntis:Project | ntis:FacilityAndEquipment |
| **ntis:greenTechnology** | Classification of green technology | ntis:Project | xsd:string |
| **ntis:hasFinalReport** | Occurrence of final report (Y/n) | ntis:Project | xsd:boolean |
| **ntis:isContinuedProject** | Existence of continued project (Y/N) | ntis:Project | xsd:boolean |
| **ntis:isSecretProject** | Existence of secret project (Y/N) | ntis:Project | xsd:boolean |
| **ntis:largeClassificationOfMinistry** | Large classification code | ntis:Project | xsd:string |
| **ntis:mainProjectNumber** | Main project No. | ntis:Project | xsd:string |
| **ntis:mediumClassificationOfMinistry** | Medium classification code | ntis:Project | xsd:string |
| **ntis:multiyearAgreement** | Classification of multiyear agreement | ntis:Project | xsd:string |
| **ntis:outcome** | Research outcome | ntis:Project | ntis:ResultEntity |
| **ntis:practicalUse** | Target of practical use (Y/N) | ntis:Project | xsd:string |
| **ntis:previousProject** | Previous project | ntis:Project | ntis:Project |
| **ntis:nextProject** | Next project | ntis:Project | ntis:Project |
| **ntis:previousProjectNumber** | Previous project No. | ntis:Project | xsd:string |
| Property                        | Description                                      | Type       |
|--------------------------------|--------------------------------------------------|------------|
| ntis:progressStatus            | Progress status                                  | ntis:Project | xsd:string |
| ntis:projectID                 | Project ID                                       | ntis:Project | xsd:string |
| ntis:projectNumber             | Project No.                                      | ntis:Project | xsd:string |
| ntis:rndClassification         | R&D classification                               | ntis:Project | xsd:string |
| ntis:rndPhase                  | R&D phase                                        | ntis:Project | xsd:string |
| ntis:sanctionInformation       | Section information                              | ntis:Project | ntis:SanctionInformation |
| ntis:smallClassificationOfMinistry | Small classification code                      | ntis:Project | xsd:string |
| ntis:subtotalAmountOfPrivateResearchFund | Subtotal of private R&D expenses | ntis:Project | xsd:float |
| ntis:technologyLifecycle       | Technology life cycle                            | ntis:Project | xsd:string |
| ntis:totalAmountOfResearchFund | Total R&D expenses                               | ntis:Project | xsd:float |

**Figure 6.** Inter-class structure diagram.

**Figure 7.** NTIS: Relationship structure.

**Figure 8.** Project class-property relationship diagram.

**Figure 9.** NTIS LOD platform.
Table 7. Interlinking between NTIS LOD and External LOD

| Category                        | Target    | Description                          | No. of Items | Remark                                                   |
|---------------------------------|-----------|--------------------------------------|--------------|----------------------------------------------------------|
| NDSL LOD                        | Paper     | NTIS paper - NDSL paper              | 111,748      | Targets issued by the NDSL                               |
|                                 | Patent    | NTIS patent - NDSL patent            | 36,192       |                                                          |
|                                 | Report    | NTIS report - NDSL report            | 85,450       |                                                          |
|                                 | Author    | NTIS researcher - NDSL author        | 24,633       | NTIS paper - NDSL paper linkage utilized                 |
| Intellectual Property Right LOD| Patent    | NTIS patent - Intellectual property right patent | 234,100     |                                                          |
|                                 | Project   | NTIS project - Intellectual property right project | 1,532      | NTIS patent - intellectual property right patent linkage utilized |
| National Bibliography LOD       | Paper     | NTIS paper - NLK paper               | 35,272       | Information identified in other LOD utilized            |
| DBpedia                         | Bio-resources | NTIS bio-resources - DBpedia bio-species | 109,308     |                                                          |
| Bio-information LOD             | Bio-information | NTIS bio-information - Nature plant | 508,031     | Nature                                                   |
|                                 |           |                                      | 1,146,266    |                                                          |

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