Applying management theories as a conceptualization lens for knowledge graphs and conceptual modeling methods

Andrei Chiş[1]

[1] Babeş-Bolyai University, Faculty of Economics and Business Administration, Teodor Mihali Street, No. 58-60, Cluj-Napoca, 400591, Romania

Abstract

This paper presents the research framing, preliminary results and future research plan of the author's on-going Ph. D. project. The project takes a design-oriented research approach to repurposing management theories as conceptualization lens for knowledge engineering. The work focuses on the Work Systems Theory, a theory introduced by S. Alter to describe enterprises with the help of a semi-structured "work system" concept. Several updates to the theory have introduced gradually more structured definitions of this concept - some of them approaching the status of metamodels or taxonomies. The Ph. D. project hereby summarized aims to push this trend towards operationalizing the WST concepts in machine-readable forms, for run-time and design-time purposes. The technologies employed for achieving this are Knowledge Graphs (RDF-based) and Metamodeling environments (ADOxx, for modeling method engineering). This doctoral summary paper reports on the preliminary results, envisioned final Ph. D. results and the literature framing of the problem from a Design Science perspective. Directed by the Design Science approach, the work started with developing an ontological schema for RDF-based knowledge graphs built according to the Work Systems Theory perspective and applied over operational data from a legacy knowledge graph available to the host organization from an earlier project. The work further aims to develop a domain-specific modeling tool inspired by WST, for aiding stakeholders to capture and manage knowledge about their work systems in a structured manner, offering a comprehensive high-level view on value creation in modern organizations. Finally, means of integrating the current work on the WST knowledge graph with the future work on the WST modeling tool will be explored towards a streamlined knowledge management approach.

Keywords

Work Systems Theory, Knowledge graphs, Design Science Research, Conceptual Modeling, Agile Modeling Method Engineering

1. Introduction

The research tackled during this Ph. D. Thesis is centered on developing an operationalization bridge for concepts from the Work Systems Theory (WST) [1], allowing their usage in a machine-readable form - as RDF-based Knowledge Graphs and as diagrammatic structures that can be linked or streamlined with the knowledge graphs. This research will be conducted by following Design Science [2] guidelines, aiming to satisfy a suite of competency questions related to richer decision support for work procedures in various organizational settings. We decided to opt for using WST as the main conceptualization frame thanks to the existence of several valuable advances on transferring enterprise metamodels to ontologies, such as [3] or [4]. Another reason is the existing background and reports on WST adoption by business professionals in multinational companies, as described in [5]. To streamline the management-oriented and the technically-oriented perspectives on knowledge management, as advocated by [6], this work aims to unify the visual templating-oriented approach of traditional enterprise modeling with the

BIR-WS 2023: BIR 2023 Workshops and Doctoral Consortium, 22nd International Conference on Perspectives in Business Informatics Research (BIR 2023), September 13-15, 2023, Ascoli Piceno, Italy
andrei.chis@econ.ubbcluj.ro (A. Chiş);
0000-0003-0173-7250 (A. Chiş);

AI-oriented approach of knowledge representation and reasoning using WST as a source of concepts for the governing metamodels and schemas.

The Work Systems Theory has been traditionally used to design and evaluate systems in enterprises and larger-scale public institutions. Any “work system” consists of human and machine performers who complete a series of tasks, having a specific purpose, obtaining clearly defined deliverables or measurable results for a "customer's" benefit. This Ph. D. work envisions information systems made operational with the help of WST-specific RDF knowledge graphs as a semantic layer over traditional enterprise knowledge graphs lifted from legacy data or created by other means. The work explores a top-down work systems integration that can remain compliant with the idea of transcending roles, which is advocated by Work Systems Theory. Concretely, the “customer” of a specific work system can be a “participant” in another one, as WST doesn’t enforce immutable roles for the actors involved in an organization’s work systems. This requires proper contextualization and granularity to be enforced by design and maintained in a machine-readable knowledge structure governing this. As any work system is composed of participants, customers and activities, all these comprising parts are being directly affected by the way digital technologies shape up the organizational environment, especially in the case of medium to large scale businesses or public institutions. Knowledge graphs have demonstrated their capabilities to offer a smooth transition in this regard, allowing users to navigate easily through data on multiple layers of aggregation and abstraction, obtaining increased quality information through semantics-driven data queries [7] and automated reasoning capabilities.

Apart from the graph conceptualization of WST, which has already been achieved in the first part of the Ph. D. program, there are also plans for developing a WST-based conceptual modeling tool. The modeling tool will allow the mapping of organizational systems according to the theory, enabling design-time knowledge management and analytics capabilities for modern organizations. The research plan is to develop the aforementioned tool by way of Agile Modeling Method Engineering (AMME) [8] as a specific flavor of a DSR engineering-evaluation cycle.

The reminder of the paper is structured as follows, according to Design Science principles [2]: Section 2 discusses the problem statement and objectives, while Section 3 provides more background info on the conceptualization of knowledge graph ontologies, relying on WST. Section 4 details the research plan and used methodologies, while Section 5 provides information regarding design decisions and results obtained so far in the ontological schema development process. Section 6 presents future research directions to be achieved in this Ph. D. thesis and Section 7 invokes related works. Section 8 concludes the article.

2. Problem context and objectives definition

2.1. Problem context

Design Science Research investigates artifacts in a context – in our case the motivating organizational context is that of a higher education institution where new procedural changes arose as a resilience plan to fight the pandemic scenario, leading to many changes in the digital facet of the institution, accompanied by a multitude changes in work procedures.

All the work procedures are written and kept solely in human natural language, lacking traceability to their operating context or motivation elements (strategy, environment incentives etc.). This makes it difficult to navigate through procedures and to understand their rationale, or to aggregate their implied resources or stakeholders in the sense that enterprise architecture analysis typically allows. Moreover, situations of non-compliance are difficult to spot when human assessors must perform all the work, instead of having information systems that could make such assessments automatically. The aforementioned organization was previously involved in the process of building an internal knowledge graph, populated with RDF graphs lifted from its legacy databases. Primary results of this effort were first reported in [9], and this thesis plans to build on top of that work by adding a semantic layer inspired by the Work Systems Theory and streamlined with a diagrammatic modeling method for managing enterprise knowledge in WST terms.

2.2. Objectives definition

By taking into account the context and challenges discussed in the previous subsection we can formulate the following problem statement according to the DSR template:

Improve ***knowledge management through richer decision support and semantic data integration in organizations*** *(problem context)*
... by treating it with a ***WST-conceptualized semantic layer that can serve knowledge engineering efforts (knowledge graph building and modeling method engineering)*** *(artifact)*
... to satisfy a need for ***analyzing how work is performed across multiple work systems, considering both run-time resources and design-time decisions involved in work procedures*** *(requirements)*
... in order to ***ensure capabilities for semantic traceability of value-creation, resources, actors, and work procedures across multiple work systems in the organization*** *(goals).*

Starting from the given problem statement the requirements can be split in two categories, according to their scope, as the research plan is to conceptualize WST for both knowledge graphs and conceptual modeling tools. For the knowledge graph conceptualization we took into account the following guiding principles:

- As described in [9], an initial knowledge graph was developed by semantic lifting of legacy relational databases in an academic setting. The WST-based semantic graph should be valuable by itself but also in conjunction with the already existing legacy graph, offering appropriate bridging to the operational data;
- Internally approved work procedures should constitute the basis for defining new granular work systems. The knowledge graph aims to define a basic but also rich enough semantic structure for traceability of work and processes obtained from legacy BPM and ERP systems;
- The knowledge graph must be able to support scenarios of non-compliance pattern detection and aggregated reporting of work and procedures across multiple work systems. WST concepts and relations must be able to provide the conceptual backbone for analyzing each of these scenarios from a high-level perspective

The second artifact, a WST-enabled modeling tool is guided by the following requirements:

- The tool should offer a drag-and-drop-based look and feel for building diagrams of work systems decomposable to appropriate granularity;
- WST concepts shall be split in model types according to their scope in order to avoid cluttering of diagrams; semantic hyperlinks will ensure meaningful relationships between different diagrams contributing to a multi-perspective WST-based enterprise model;
- The tool shall offer basic work systems analytics and visual traceability capabilities, without needing to export diagrams to a different system;
- The tool shall offer RDF-based interoperability with the knowledge graph.

This final integrative aspect is related to interconnecting the WST-enabled ontology to the WST-enabled modeling tool. Even though they could be regarded as separate projects at a first glance they must form together a knowledge management method. The modeling tool will become an enabler for integrating the WST-based ontology developed in the first part, into medium to large scale organizational systems.

3. WST-enabled conceptualization of knowledge graphs ontology

Structurally, Work Systems Theory is built on six main elements: *Customers*, *Products* or *Services*, *Processes* and *Activities*, *Participants*, *Information* and *Technologies*. Any work system as described in [1] has a series of customers who need to obtain a set of products or services from a specific work system. The customers can either be external to the organization or internal customer who need these resulted outcomes as input for their own tasks. In order to obtain products, a series of processes and activities must be completed by participants, relying on information and technologies. The customer of a work system can be a participant in another work system and vice versa so the roles have a high degree of interchangeability, from one work system to another. Other aspects present in WST are the *Environment* - as any work system operates in an environment, the *Infrastructure* – because any work system must be supported by a particular infrastructure made of technical and non-technical components and *Strategies* – which are enabled by the work system in cause. The way a work system is organized can be structured according to the categories depicted in Figure 1.

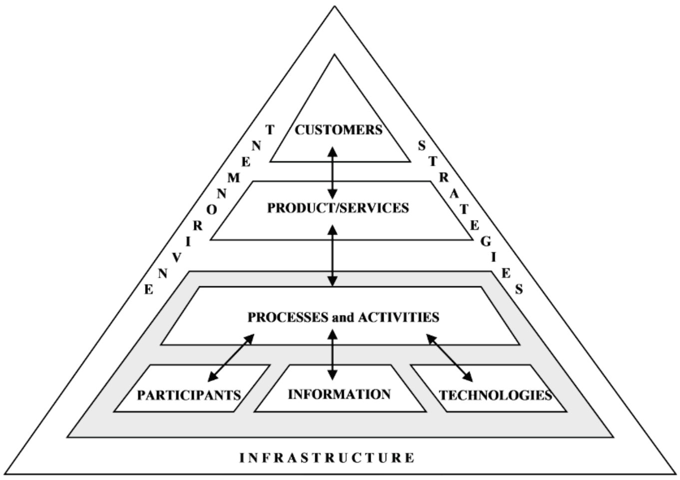

Figure 1. The Work Systems Framework. Source: [1]

There are a series of scientific works such as [1], [10] or [11] which expanded and refined several metamodels for Work Systems over time. We used these articles as a starting base for conceptualizing the ontology of the WST-enabled knowledge graphs that was developed so far for this Ph. D. Thesis. The research plan is to continue with a new conceptualization layer, in a dedicated enterprise modeling tool that will distinguish itself from process centric notations like BPMN, offering a higher-level system perspective on value creation, involved actors, processes and resources.

The modeling tool that is currently in development process, alongside the ontology previously mentioned will increase knowledge management capabilities, by adding a new semantic navigability layer through richer queries and semantic-enabled agents. It transforms WST from a framework of designing and evaluating work systems into a knowledge acquisition lens for modern organizations.

4. Research plan and methodology

4.1. Research plan

The research plan for this Ph. D. thesis can be summarized in three stages:

1. In the first part scientific literature was studied and we came to the conclusions that conceptualizing WST on a knowledge graph ontology could provide a step forward in regards to designing, analyzing and tracing value in work systems. The literature research work was

done by surveying state of the art literature related to *Work Systems Theory*, *Enterprise Knowledge Graphs* and *Conceptual Modeling Method Engineering*. Some of these works are detailed in Section 7. Articles like [12] describe the creation of metamodels conceptualized on specific information management theories, but they don't always reach to the status of operational artifacts. The work done in this Ph. D. project bridges this gap with knowledge structures that can be used either in relation to run-time traces of work systems or with design-time decisions;

2. Secondly, the research and engineering methodology were chosen for all the artifacts to be developed. As mentioned earlier, Design Science Research and Agile Modeling Method Engineering were used. Currently, the plan is to have three Design Science and AMME iterations for each artifact. On the first subproject related to WST-enabled ontology, the initial DSR iteration was successfully completed with a draft of the knowledge graph being subjected to scalability tests on a GraphDB licensed installation. On the WST-enabled modeling tool development side the project is currently at the beginning of the first Design Science and AMME iterations. The first DSR iteration from the ontology development artifact is synched to the DSR iterations from the WST-enabled modeling tool development research project as the obtained ontology constitutes the foundation for the metamodel of the second artifact;
3. A first ontology for WST-based knowledge graphs was developed during the first DSR iteration and started subjecting it evaluations from competency and scalability perspectives;
4. The fourth step of the research plan is represented by developing a conceptual modeling tool for work systems design and analysis. This phase was recently initiated and we're discussing early metamodel drafts before starting an ADOxx-based implementation. AMME and Design Science will be continuously employed to obtain the expected results in the form of a diagrammatic tool.

In regards to the evaluation of resulting artifacts, the plan is to perform a series of quantitative and qualitative measures, related to the achievement of research goals inspired by the criteria taxonomy in [13].

On the quantitative evaluation side we plan to measure execution times for running queries on knowledge graphs or automatically generating graph instances and diagrams with the modeling tool. This phase is ongoing currently as we are still performing measurements on our artifacts.

The qualitative evaluation will assess how end-users interact with our artifacts when it comes to querying knowledge graphs or designing work systems with our modeling tool. The plan is to use a series of questionnaires for measuring how easily users are able to achieve desired goals with the aforementioned artifacts and also a script that follows each click and action performed by users in the modeling tool will be implemented, helping us to see in real time how the modeling effort is going. Another aspect would evaluating in accordance to Moody's principles of semantic transparency [14]. The qualitative measurements hasn't been rolled out yet.

4.2. Research methodology: Design Science

Due to the artifact-oriented nature of our research we chose Design Science as the overarching research methodology for this Ph. D. Thesis. We started DSR iterations having the requirements captured in Section 2 as our foundation for all the modeling tools and artifacts developed as part of this Thesis. Design Science framing is achieved by complying with the suite of phases [15] present in any research which follows this methodology.

1. In the Problem Identification step we surveyed state of the art literature, concluding that we need to center our research around conceptualizing WST as a layer for knowledge graphs in order to improve knowledge acquisition and work systems analytics capabilities. These main research objectives must be achieved in a frictionless manner, as we also aim to develop a Work Systems Theory enabled modeling tool, leading to richer capabilities for work systems analytics;
2. In the Objectives Statement phase we defined the drivers of our research as described earlier in Section 2;

3. The Design and Development phase is an ongoing step at the current time. We have already developed a preliminary graph ontology for enabling WST-based organizational graphs and the WST modeling tool is a work in progress, furtherly detailed in Section 5.
4. In the Demonstration step a larger-sized academic institution work system was mapped on the developed ontology. Concretely, we wanted to assess the ability of our artifact to represent an equipment procurement work system, having a clear view on the work system as a whole;
5. During the Evaluation phase, the obtained treatment was analyzed quantitatively by measuring the speed and performance of specific queries ran on the knowledge graphs developed based on the ontology. Qualitative measurements were performed by using the WST-enabled ontology to answer a series of competency questions. We plan to use the same evaluation approaches when the modeling tool will enter the evaluation phase.
6. The Communication phase consists of disseminating our work through a series of articles that are currently under review;

4.3. Engineering methodology: Agile Modeling Method Engineering

The chosen engineering methodology for developing the aforementioned WST-enabled modeling tool is Agile Modeling Method Engineering (AMME) [8] due to its similarity to Agile [16] methodologies used in software development and support for incremental development of artifacts. When developing modeling tools, modeling requirements tend to evolve during the process as more domain-specific knowledge is incorporated gradually.

AMME relies on a *Produce-Use* cycle, which can be split into 2 sub-cycles: *Conceptualization* and *Modeling* [8], as described in the following:

- The Conceptualization cycle can be split in 5 agile iterations: Creation, Design, Formalize, Develop and Deploy. In the *Creation* phase, stakeholder data are analyzed, being tied to *Problem Identification* phase from DSR, leading to the definition of research objectives. The *Design iteration*, where the metamodel is developed and the needed functionalities are set, alongside *Formalize*, where the graphical notations and the elements of syntax and semantics of the modeling tool are defined and *Develop*, where the conceptual functionalities are coded and turned into reality can be mapped on the *Design and Development* phase from Design Science Research, as the modeling artifact takes shape, being subject to changes when such situations arise. The *Deploy* iteration, where the modeling artefact is used on different real world scenarios is tied to the *Demonstration* phase from DSR;
- The Modeling cycle follows the usage of the developed artefact in modeling processes, executing them using the added functionalities and then evaluating the results. It is strongly tied to undergoing the *Evaluation* phase described in Design Science Research methodology;

4.4. Technological enablers

In order to develop the WST-based knowledge graph ontologies and modeling tools which represent the main contributions of this thesis we needed the following ingredients, necessary to achieve the desired conceptual design, successfully developing modeling language constructs and functionalities:

- A fast prototyping environment, represented by ADOxx metamodeling platform [17], used alongside its proprietary scripting language, AdoScript [18]. ADOxx brings a supplementary level of agility when it comes to designing modeling languages, ensuring a quick transition from the metamodel creation phase to the actual language constructs implementation phase. AdoScript serves as the key ingredient in developing modeling functionalities such as model parsing or transforming modeling concepts into runnable code, which provides one of the key enablers of the model-driven software engineering facets [19].
- Another key technology used in our research is represented by semantic graph databases, namely GraphDB [20] in correlation with SPARQL [21] as querying language. We relied on

semantic technologies in one of the works which are in reviewing phase, where we bridged the design-time view with run-time data found in legacy systems, coming as an aid for the Work Systems Theory (WST) [10].

5. Design decisions and early results

The elements from the Work Systems Theory were conceptualized into a governing schema for knowledge graphs. The elements presented in Figure 1 were adjusted in order to support the implementation of semantic ontologies.

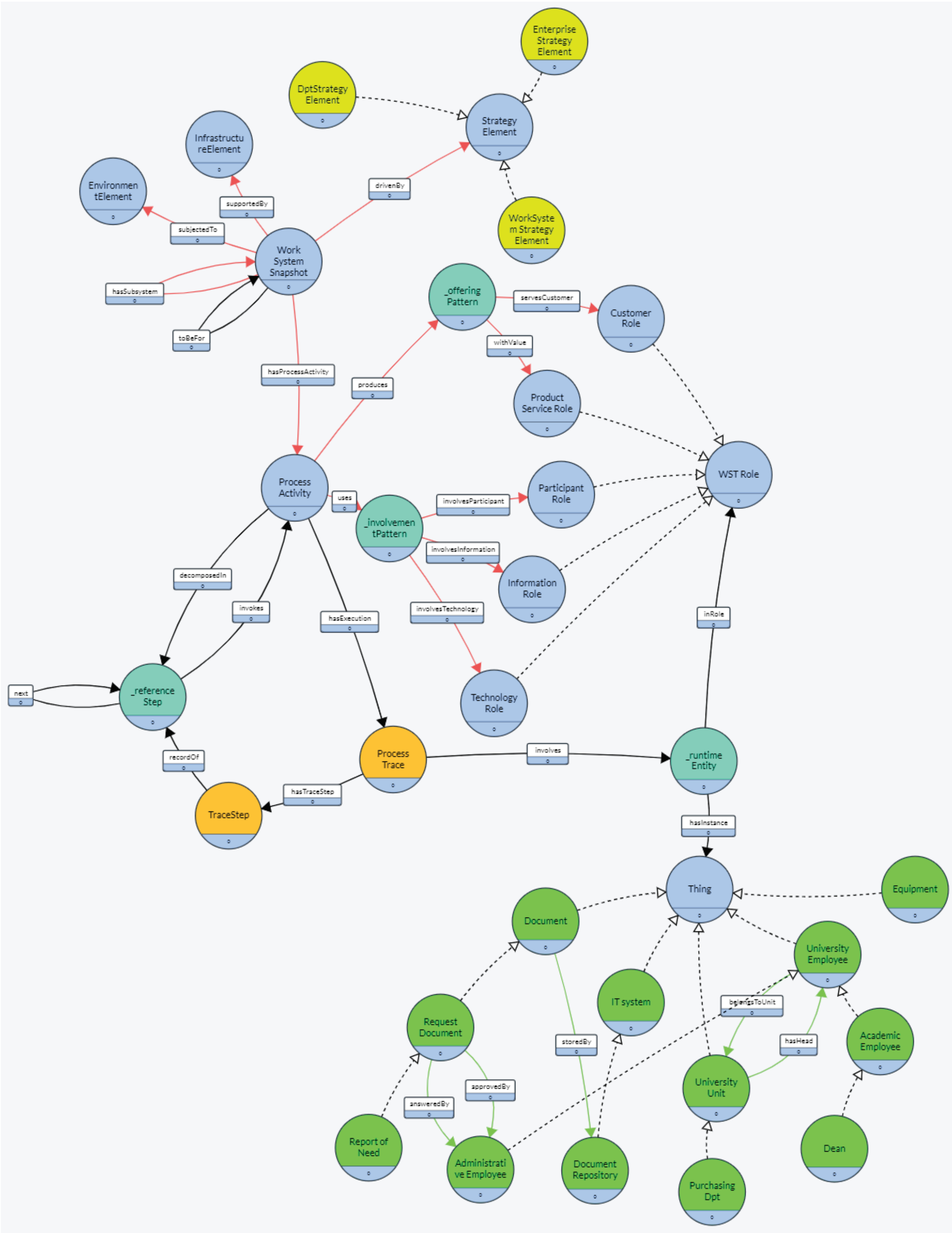

Figure 2: The Governing Schema for WST-enabled Knowledge Graphs

On the side of specific WST concepts, as seen in Figure 2, the schema is made of the following elements: *WorkSystemSnapshot* – that acts as the depiction of one analyzed work system of convenient granularity, *EnvironmentElement*, *InfrastructureElement* and *StrategyElement* – which serve as representations for concepts external to the work system, *ProcessActivity* – which can be decomposed into more granular *steps*. There is also a mechanism of showing the roles from a work system through the *WST Role* concept which acts as a superclass for *CustomerRole*, *Product Service Role*, *Participant Role*, *Information Role* and *Technology Role* – serving as conceptualizations for internal work systems elements. In our ontology we also needed to add the *Thing* concept which is the base of instantiation for the concrete composing elements of a work system. The relations between concepts are showcased below:

- On the side of external relationships to a work system the following relations were defined: to an *Environment* element - *subjectedTo*, to an *Infrastructure* Element - *supportedBy* and to a *Strategy* element - *drivenBy*. As discussed earlier, all these elements are not involved directly in a WS, but rather they shape execution flows and processes by offering a context in which a work system is able to operate or motivation for its operation;
- Internal relationships are tied to processes or activities, being separated in 2 types of concrete relationships: *Offering Pattern* – for showing situations in which an organizational actor is the customer of a process or activity and *Involvement Pattern* – when an organizational actor is a participant in a specific process or activity;
- Processes must have decomposition capabilities, as any process can be formed of a suite of activities or sub-processes. These granular elements become the core of smaller work systems – the *hasSubsystem* relation offering the ability to show relations between a work system and its sub-system components. An activity can be decomposed in a series of steps, which leads to the existence of *decomposedIn* relations. In this case, we also have the next relationship which shows the succession between particular steps;
- Work Systems Theory allows interchangeable roles, from one process to another, as one employee can be the customer of a process but then they can be participants in another process. In this case, connecting instances to a work system would lead to an n-ary relationship thus we needed to include *ParticipantRole* which is connected to an *involvementPattern* through an _*involvesParticipant* relation. In this case navigating from a WS snapshot to a specific participant can be done avoiding potential ambiguity caused by n-ary relationships;

The knowledge graph from Figure 2 depicts a particularized schema for a university equipment procurement work system. In the lower part there can be seen subclasses of *Thing* which represent concrete composing elements, tailored to the scope of the knowledge graph, as *University Employee*, *University Unit*, *Dean* or *Report of Need*. This way, high level concepts of WST like *Customers* or *Participants* are brought to a scenario specific needed level of detail. The same idea can be applied to all the components of Work Systems Theory, which can be particularized thanks to the developed ontology.

Semantic queries can be regarded as proxies for competency questions, having the purpose to serve as an evaluation approach for knowledge graphs [22]. The queries were executed directly into a GraphDB [20] instance but a future DSR iteration will bring a dedicated web client for viewing and querying WST-enabled knowledge graphs.

In the following we'll exemplify semantic queries corresponding to two competency questions: the first aims for extracting instance data by applying the lens of WST roles, while the second one will ignore instance level data, but it will rely on fructifying the enabled conceptualization layer between domain-specific concepts and WST roles.

Competency question 1: *Who benefited across all work systems driven by the IT upgrade strategy, what products/services did they get and in what unit do they work?*

```
SELECT ?customer ?unit ?productService
WHERE   {
        ?system :drivenBy :ITUpgrade;
                :hasProcessActivity/:hasExecution ?trace.
```

```
?trace :involves [:hasInstance ?customer;
                  :inRole/a :CustomerRole],
                 [:hasInstance ?productService;
                  :inRole/a :ProductServiceRole].
?customer :belongsToUnit ?unit.
}
```

Competency question 2: *What participants were dropped in the To-Be version of the Equipment Acquisition work system snapshot?*

```
SELECT ?participant
WHERE
    {
    ?system2 :toBeFor :EquipmentAcquisition;
             :hasProcessActivity/:uses/:involvesParticipant ?participant.
    FILTER NOT EXISTS
           {:EquipmentAcquisition :hasProcessActivity ?process.
           ?process :uses/:involvesParticipant ?participant.}
    }
```

The current DSR iteration managed to achieve a prototype level ontological schema for adding a Work Systems Theory inspired conceptualization lens for knowledge graphs. The approach aims to become an important aid in bridging design-time and run-time views of work systems, allowing relevant stakeholders to benefit from a comprehensive semantic layer when navigating instances of work systems. Moreover, by exploiting the capabilities of semantic technologies we can add AI-empowered reasoning capabilities to work systems in future Design Science Research iterations.

6. Next steps

Future work will be oriented towards developing a WST-supported modeling tool for knowledge acquisition and management, offering increased capabilities for mapping organizational processes, entities and value flows from a high-level view.

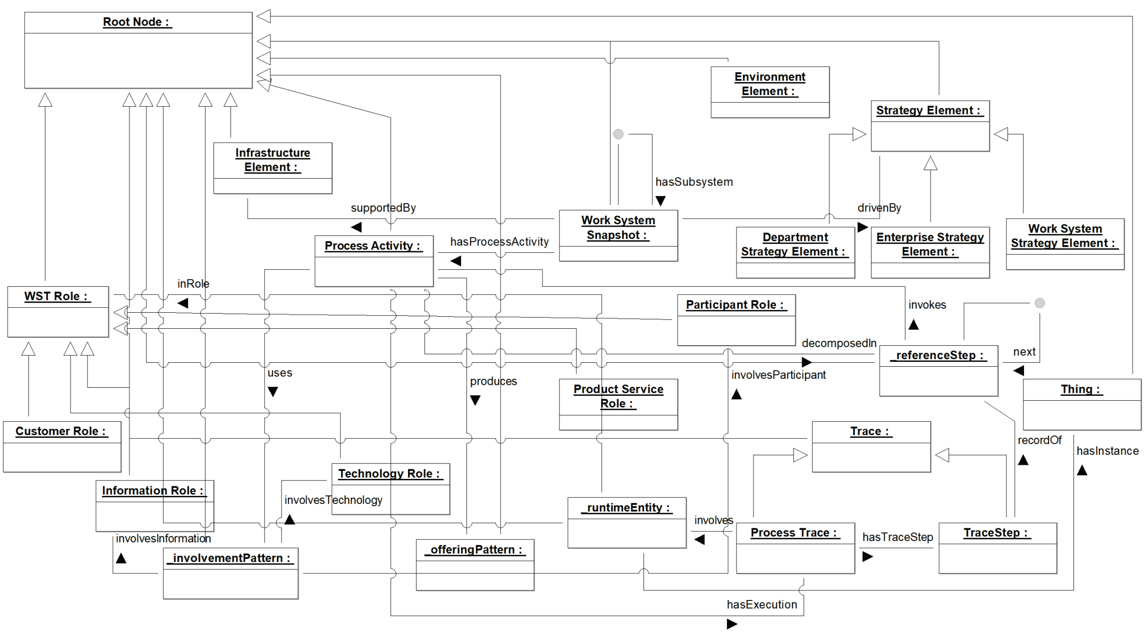

Figure 3. Preliminary metamodel of the WST-enabled modeling tool

As a starting point for this artifact we will use the ontology schema presented in Section 5, alongside works containing refined WST metamodels, published over the years [1, 10, 11, 23, 24]. Hereby a preliminary metamodel for the WST-based tool is proposed, as seen in figure 3, inspired by the ontological schema developed as a conceptualization lens for knowledge graphs (see Fig. 2). The presented metamodel might be adjusted with new concepts during several DSR iterations until we will obtain a version of the modeling tool itself that can be described and published in a new paper. In Figure 3, relations between concepts are presented as association lines in UML terminology, having a triangle marker expressing direction. For example "A Process Activity uses an _involvementPattern", meaning that for the uses relation, its domain is Process Activity, while the range is _involvementPattern.

In regards to functionalities of our WST-enabled modeling tool we plan to develop RDF graph serialization of diagrams and analytics capabilities directly in the modeling tool. On the RDF graph serialization of diagrams part, we have previous experience which was materialized in developing a modeling tool for designing knowledge graphs which is currently under review at a well-renown conference.

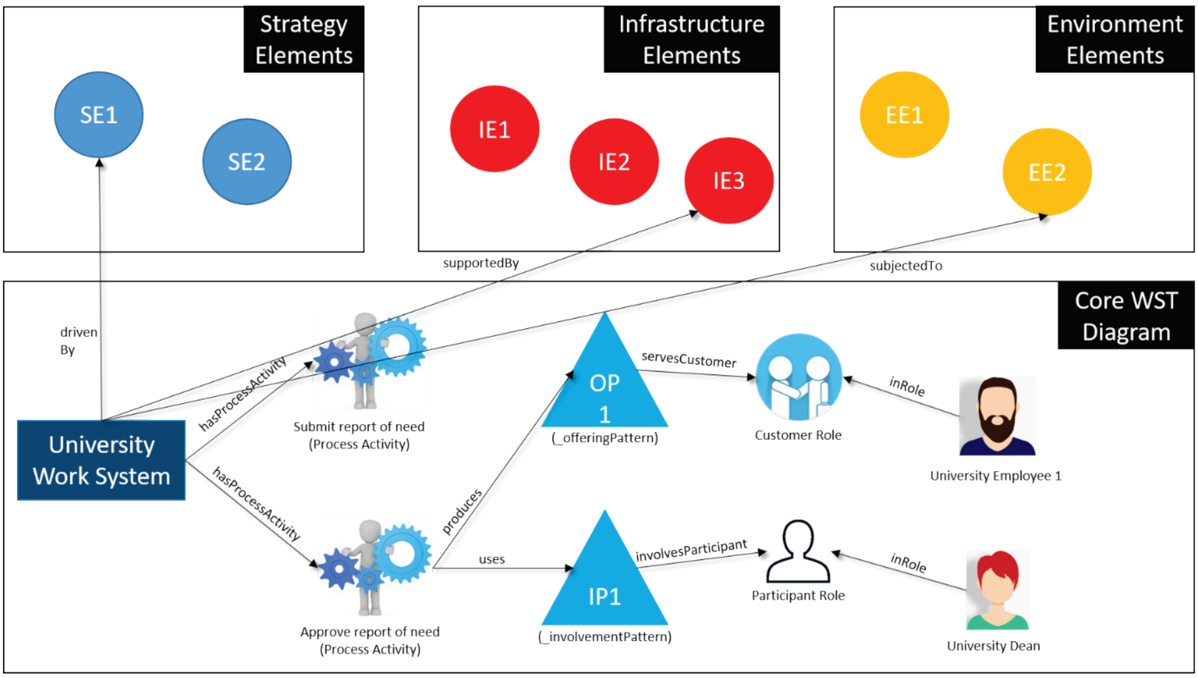

Figure 4. Mockup diagram for the WST-enabled modeling tool

Figure 4 represents a mockup diagram of how a WST diagram made with the WST-enabled modeling tool could look like, by using the artifact in its early stages. The plan is to implement a few different model types in order to capture all necessary information and provide a clear separation of concepts. In the *Core WST Diagram* model there will be kept the main concepts derived from Work Systems Theory, which are introduced in Figure 2, such as *Processes & Activities*, different roles which can be fulfilled by entities, the work system itself which has a series of processes and activities and the rest of core work system related elements. Regarding *Strategies*, *Infrastructure* or *Environment*, which are elements that shape the development and execution of activities inside a work system, the plan is to keep them in separate diagrams as seen in Figure 4, in order to decrease cognitive load and provide a clearer separation of concerns. Linkage between entities from different model types, as seen in the upper part of Figure 4 will be performed through inter-model semantic links, named *interrefs* in ADOxx terminology. Another important aspect will be incorporating Moody's principles [14] for offering domain-specific notation that can be easily grasped by practitioners in the modeling tool.

In the following some potential competency questions are presented, which could be used to evaluate the WST-enabled modeling tool. Such examples could be *"What strategies drive Work System X.1?"*, *"Who are the participants involved in each process of Work System X.1?"* or *"What is the Process Trace that serves Customer A in Work System X.1?"*. Executing related queries on diagrams will showcase the achieved semantic traceability of value with the modeling tool, also allowing us to directly measure performance similar to the case of the graph ontology.

7. Related works

Information systems rely on schemas, which serve as formal information models for their data repositories. These schemas, to some extent, imply the semantics of the information stored within them and represent specific perspectives on domain conceptualization. The study of Xue et al. [25] delves into the theoretical underpinnings of ontologies and introduces the concept of ontological views as an extension of traditional ontologies. It proposes the utilization of ontological views to tackle the challenges associated with semantic integration. The proposed approach leverages schemas to create local ontological views, explores the data instances within the information systems to uncover semantic relationships among concepts within these views, and constructs a domain ontological view by leveraging discovered equivalence mappings. Our work also proposes an ontological schema for providing a high-level view on work system, relying on the concepts proposed by Steven Alter [1]. In our approach we bridge a management design-time perspective on work systems to a run-time perspective for running queries and obtaining valuable organizational information.

The work of Liu et al. [26] proposes an ontology learning model, called domain ontology graph (DOG) that is able to generate ontology graphs, having domain-specific knowledge lifted from organizational text documents. In addition to the proposed Document Ontology Graph (DOG), the research defines two types of ontological operations: document ontology graph generation and ontology-graph-based text classification. To assess the efficacy of the proposed strategy, the authors conducted simulation studies utilizing Chinese text data. These studies aimed to demonstrate the potential effectiveness of this approach by generating DOGs that represent domain knowledge and performing text classifications using the generated ontology graph.

Dong et al. [27] propose the process knowledge graph modeling method which is aimed at enabling efficient reusability information in the process of building ships on a shipyard. Starting from a 3D model of ships, authors' method is capable of building process graphs by semantic and concept mapping. This way, a unified model representation of heterogeneous ship model semantic is constructed, encompassing all the operations necessary for building that specific vessel. The authors employ a multi-strategy ontology mapping method that bridges the gap between the entity model and the process knowledge graph, leading to decreasing design cycles times and better knowledge reuse in the process of designing heterogeneous ship models. This article presents a way of adding a conceptualization layer to knowledge graphs with applications directly in industrial processes, while the work at hand is oriented towards building and analyzing work systems on a higher, conceptual level. In our case, the scope of ontologies isn't aimed at representing and storing knowledge about specific physical objects, but at providing the means for evaluating and analyzing work systems, which are composed of more actors, processes, activities and physical elements.

The work done in [28] presents a disaster management framework based on a responsibility matrix lifted from real-world cases, which is underpinned by an ontology. Named as the Disaster Management Ontology (DMO), this ontology-based framework facilitates task allocation among relevant authorities at different stages of a disaster. Additionally, it serves as a knowledge-driven decision support system for providing financial assistance to victims. In the proposed DMO, ontology is employed for knowledge integration and as a working platform for reasoners. The Decision Support System (DSS) ruleset is formulated using the Semantic Web Rule Language (SWRL), which is based on the First Order Logic (FOL) concept. Furthermore, OntoGraph, a class view of taxonomy, enhances the interactivity of the taxonomy for users. This work presents another case of applying conceptualization lenses for knowledge graphs aimed at facilitating knowledge management on real world scenarios, with a strong impact in aiding recovery plans in natural disasters scenarios. The work showcased in this paper also promises to become an important aid for knowledge reuse and obtaining increased efficiency in scenarios that can be found in day-to-day work inside medium to large scale organizations. A WST-based approach could also be rolled out on designing and analyzing life-saving systems, as WST has a high grade of applicability on any sort of work system.

8. Conclusions

The WST-based knowledge graph and the WST-based modeling tool are intended to be complementing tools of a higher level knowledge management method that will ultimately encompass the Ph. D. results under an overarching frame answering the DSR problem template formulated in Section 2. For now the two parts are somewhat disjoint, the knowledge graph aiming for integration with run-time data from legacy systems, while the modeling tool will focus on design-time decision support. Interoperability opportunities between the two remain to be investigated, considering the already reported experiences with the ability to convert ADOxx-based diagrammatic models to RDF as advertised by the "model-as-a-service" approach in the OMiLAB Digital Innovation environment [29].

So far we have achieved a first functional WST-based ontology for knowledge graphs, which was detailed in a paper that is currently under review. We plan to run 2 more DSR iterations on this side, until we reach a more mature and scalable ontology. In parallel, the development of the WST-enabled modeling tool, for enhanced design and analytics capabilities of work systems in modern organizations, will also be started. These two artifacts will be coupled, being the main pillars of the knowledge management method that we plan to obtain until the end of the Ph. D. Thesis.

References

[1] S. Alter, Work system theory: Overview of core concepts, extensions, and challenges for the future, Journal of the Association for Information Systems, 14.2 (2013): 72–121. doi:10.17705/1jais.00323.

[2] R. J. Wieringa, Design Science Methodology for Information Systems and Software Engineering. Berling, Heidelberg: Springer Berlin Heidelberg, 2014. doi:10.1007/978-3-662-43839-8.

[3] A. Harkai, M. Cinpoeru, R. A. Buchmann, The "What" Facet of the Zachman Framework – A Linked Data-Driven Interpretation, in: Proceedings of CAISE 2018 work-shops, Springer, 2018, pp. 197-208. doi: 10.1007/978-3-319-92898-2_17.

[4] M. Smajevic, S. Hacks, D. Bork, Using Knowledge Graphs to Detect Enterprise Architecture Smells, in: Proceedings of PoEM 2021, Springer, 2021, pp. 48-63. doi: 10.1007/978-3-030-91279-6_4.

[5] T. Köhler, S. Alter, B. H. Cameron, Enterprise modeling at the work system level: evidence from four cases at DHL Express Europe, in: Proceedings of PoEM 2018, Springer, 2018, pp. 303-318. doi: 10.1007/978-3-030-02302-7_19.

[6] D. Karagiannis, R. Buchmann, M. Walch, (2017). How Can Diagrammatic Conceptual Modelling Support Knowledge Management?, in: Proceedings of the 25th European Conference on Information Systems (ECIS), AIS Research Papers, 2017, pp. 1568-1583. URL: https://aisel.aisnet.org/ecis2017_rp/101.

[7] J. Z. Pan, G. Vetere, J. M. Gomez-Perez, H. Wu (Eds.), Exploiting Linked Data and Knowledge Graphs in Large Organisations, Springer Cham, 2017. doi: 10.1007/978-3-319-45654-6.

[8] D. Karagiannis, Agile modeling method engineering, in: Proceedings of the 19th Panhellenic Conference on Informatics, Association for Computing Machinery, 2015, pp. 5–10. doi: doi.org/10.1145/2801948.2802040.

[9] R. A. Buchmann, R. Dragoș, A. M. Ghiran, From the Application-Centric to the Knowledge-Centric University: A Design Science Proof-of-Concept, in: Proceedings of ISD 2021, Valencia, Spain. URL: https://aisel.aisnet.org/isd2014/proceedings2021/currenttopics/14/.
[10] D. Bork, S. Alter, Satisfying Four Requirements for More Flexible Modeling Methods: Theory and Test Case, Enterprise Modelling and Information Systems Architectures (EMISAJ), 15 (2020). doi: 10.18417/emisa.15.3.
[11] S. Alter, J. C. Recker, Using a work system perspective to expand BPM research use cases, Journal of Information Technology Theory and Application, 18.1 (2017): 47-71. URL: https://aisel.aisnet.org/jitta/vol18/iss1/3.
[12] E. Maleki, F. Belkadi, A. Bernard, A Meta-model for Product-Service System based on Systems Engineering approach, Procedia CIRP, 73 (2018): 39-44. doi:10.1016/j.procir.2018.04.016.
[13] N. Prat, I. Comyn-Wattiau, J. Akoka, Artifact Evaluation in Information Systems Design-Science Research – A Holistic View (2014), in: Proceedings PACIS, 2014, 23. URL: https://aisel.aisnet.org/pacis2014/23.
[14] D. Moody, The “Physics” of notations: towards a scientific basis for constructing visual notations in software engineering, IEEE Transactions on Software Engineering, 35.5 (2009): 756–779. doi: 10.1109/TSE.2009.67.
[15] K. Peffers, T. Tuunanen, M. Routenberger, S. Chatterjee, A Design Science Research Methodology for Information Systems Research, Journal of Management Information Systems, 24.3 (2008), pp. 45–77. doi:10.2753/MIS0742-1222240302.
[16] The Agile Manifesto. URL: https://agilemanifesto.org/. Last accessed on 18.07.2023.
[17] The ADOxx Metamodeling Plaform. URL: https://www.adoxx.org/live/home. Last accessed on 15.07.2023.
[18] The AdoScript Scripting Language. URL: https://www.adoxx.org/live/adoscript-documentation. Last accessed on 15.07.2023.
[19] R. A. Buchmann, M. Cinpoeru, A. Harkai, D. Karagiannis, Model-Aware Software Engineering – A Knowledge-based Approach to Model-Driven Software Engineering, in: Proceedings of the 13th International Conference on Evaluation of Novel Approaches to Software Engineering, ScitePress, 1, 2018, pp. 233–240. doi:10.5220/0006694102330240.
[20] The GraphDB Semantic Graph Database. URL: https://graphdb.ontotext.com/. Last accessed on 17.07.2023.
[21] The SPARQL Query Language for RDF. URL: https://www.w3.org/TR/rdf-sparql-query/. Last accessed on 18.07.2023.
[22] C. Bezerra, F. Freitas, F. Santana, Evaluating ontologies with competency questions, in: 2013 IEEE/WIC/ACM International Joint Conferences on Web Intelligence (WI) and Intelligent Agent Technologies (IAT), IEE, 3 (2013). doi:10.1109/WI-IAT.2013.199.
[23] S. Alter, S., Extending a Work System Metamodel using a Knowledge Graph to support IS visualization and development, in: Proceedings of the ER forum and PhD symposium @ ER 2022, CEUR-WS 3211, 2022. URL: https://ceur-ws.org/Vol-3211/CR_110.pdf.
[24] S. Alter, Degree of encapsulation as key concern in analysis and design for service systems, in: Proceedings of AMCIS 2016, AIS eLibrary, 2016. URL: https://aisel.aisnet.org/amcis2016/SAND/Presentations/4/.
[25] Y. Xue, H. H. Ghenniwa, W. Shen, Instance-based domain ontological view creation towards semantic integration, Expert Systems with Applications, 38.2 (2011): 1193-1202, doi:10.1016/j.eswa.2010.05.012.
[26] J. N. K. Liu, Y. L. He, E. H. Y. Lim, X. Z. Wang, A New Method for Knowledge and Information Management Domain Ontology Graph Model, IEEE Transactions on Systems, Man, and Cybernetics: Systems, 43.1 (2013): 115-127. doi:10.1109/TSMCA.2012.2196431.
[27] J. Dong, X. Jing, X. Lu et al., Process knowledge graph modeling techniques and application methods for ship heterogeneous models, Sci Rep, 12, 2911 (2022). doi:10.1038/s41598-022-06940-y.
[28] D. Shukla, H. K. Azad, K. Abhishek et al., Disaster management ontology - an ontological approach to disaster management automation, Sci Rep, 13, 8091 (2023). doi:10.1038/s41598-023-34874-6.

[29] D. Karagiannis, R. A. Buchmann, W. Utz, The OMiLAB Digital Innovation environment: Agile conceptual models to bridge business value with Digital and Physical Twins for Product-Service Systems development, Computers in Industry, 138 (2022): 103631. doi:10.1016/j.compind.2022.103631.