Addendum: Valorization

Remark: This addendum is required by the regulation governing the attainment of doctoral degrees (2013) of Maastricht University. As stated there, the addendum "does not form part of the dissertation and should not be assessed as part of the dissertation".

The ability to transfer data between information systems, also referred to as *interoperability* between systems, presents an ever-growing issue in a society which adopts electronic solutions in a growing range of domains. If this data is not standardized, it becomes necessary to apply a transformation to the data, based on a given mapping, in order to make the data transfer possible. In section 1.2 we introduced a wide range of applications for the presented research of this thesis, where it is required for data to be exchanged between information systems. These application include schema integration, information integration, ontology engineering, information sharing, web-service composition, querying of semantic information and agent communication.

In the following sections, we will introduce three real-world domains, namely (1) the US Capital Facility Industry, (2) the US Automotive Industry and (3) the US Health Care Industry, which regularly face interoperability issues. These issues are typically resolved via conventional means, resulting in operational inefficiencies and added costs. Examples of such conventional means are transforming and entering data into different systems by hand, redesigning information systems due to incompatibility or outsourcing information exchange responsibilities to third parties. We present the results of three scientific studies which attempted to quantify the annual costs, that these domains are forced to compensate for, due to unresolved interoperability issues. Interoperability costs are compiled by estimating factors such as added labour costs of data transformation and verification, added labour costs of reworking and redesigning ongoing projects due to unexpected incompatibilities, purchase costs of new systems and resources, delay costs and lost revenue costs.

Cost Estimate: US Capital Facility Industry

The so called *Capital Facility* industry is a component of the entire US construction industry. The core activities of this industry encompass the design, construction and maintenance of large buildings, facilities and plants. These buildings are ordered by commercial, industrial and institutional sectors. Due to the large scale of typically requested buildings, the capital facility industry has large data requirements. Examples of data exchange in this sector is the sharing of data among all stakeholders, possibly across several information systems, and the integration of multi-vendor equipment and systems. Due to these requirements, the capital facility industry is particularly vulnerable to interoperability issues.

In 2004, the Building and Fire Research Laboratory and the Advanced Technology Program at the National Institute of Standards and Technology (NIST) issued a study to estimate the inefficiencies caused by interoperability issues between computer-aided design, engineering and software systems. This study has been performed by RTI International and the Logistic Management Institute (Gallaher *et al.*, 2004). The following stakeholders were identified which typically face direct interoperability issues during the execution of a project:

Architects and Engineers covering architects, general and speciality engineers, and facilities consultancies.

General Contractors covering general contractors tasked with physical construction and project management.

Speciality Fabricators and Suppliers covering speciality constructors and systems suppliers, including elevators, steel, and HVAC systems.

Owners and Operators covering the entities that own and/or operate the facilities.

Participants from each stakeholder group contributed to the study through interviews with the experimenters or by completing surveys. The participants were tasked to quantify their incurred interoperability costs by listing which activities they perform in order to resolve these issues. By extrapolating the costs associated with these activities, a cost estimate could then be established. The activities and their associated costs were grouped into three categories: (1) avoidance costs, (2) mitigation costs and (3) delay costs. Examples of avoidance costs are the costs of outsourcing of translation services to third parties, investing in in-house programs and the costs of purchasing, maintaining and training for redundant computer-aided design and engineering systems. Mitigation costs typically involve the costs associated with rework of designs or construction, re-entering data when automated transfer systems fail and information verification. Examples of delay costs are costs of idle resources due to delays, lost profits due to delay in revenues and losses to customers and consumers due to project delays. An overview of the estimated costs for each stakeholder group can be viewed in Table A.

Stakeholder Group	Avoidance Costs	Mitigation Costs	Delay Costs	Total
Architects and Engineers	485,3	684.5	-	1,169.8
General Contractors	1,095.4	693.3	13.0	1,801.7
Speciality Fabricators and Suppliers	1,908.4	296.1	-	2,204.5
Owners and Operators	3,120.0	6,028.2	1,499.8	10,648.0
All Stakeholders	6,609.1	7,702.0	1,512.8	15,824.0

Table A: Annual cost of inadequate interoperability in the US capital facility industry by cost category, by stakeholder group (in $Millions)(Gallaher *et at.,* 2004).

As we can see in Table A, the capital facility industry has to compensate for substantial interoperability costs. The total costs are estimated at $15.8 billion annually, which corresponds to approximately 3-4% of the entire industry's annual revenue.

Cost Estimate: US Automotive Industry

In 2002, the Research Triangle Institute conducted a study for the National Institute of Standards and Technology (NIST) in order to quantify to what degree the US Automotive supply chain suffers from interoperability issues (Brunnermeier and Martin, 2002). Similar to the previous study, the experimenters surveyed different stakeholders across the industry about typically faced interoperability problems. The costs of the provided answers are extrapolated in order to estimate the severity of these costs across the entire automotive industry. This estimate is referred to as the *Cost Component Approach*. The experimenters also interviewed several key industry executives about their viewpoints. The executives provided their own estimates of the incurred interoperability costs, allowing for the inclusion of costs which might not have been considered by the experimenters. This method of cost estimation of referred to as the *Aggregate Cost Approach*. An additional benefit of consulting industry executives is that it validates the results of the *Cost Component Approach* if their results are similar to a certain degree. The cost estimates of both approaches can be viewed in Table B.

The results of both estimates depict that the automotive industry suffers significant monetary losses due to interoperability issues. According to the *Cost Component Approach* $1.05 billion are lost yearly, while the *Aggregate Cost Approach* resulted in a cost estimate of $1.015 billion.

Source of Cost	Annual Cost ($Millions)	Percentage
Cost Component Approach		
Avoidance Costs	52.8	5
Mitigation Costs	907.6	86
Delay Costs	90.0	9
Total	1,050.4	100
Aggregate Cost Approach		
Interoperability Cost	925.6	91
Delayed Profits	90.0	9
Total	1,015.6	100

Table B: Aggregate of estimated annual interoperability costs of the US automotive industry (Brunnermeier and Martin, 2002).

Net Value Estimate: US Health Care Industry

The health care sector sees an every increasing use of information technology. Commonly used technologies in this sector are the storage of patient data in electronic medical records, computerized physician order entry systems, and decision support tools. Facilitating easy information exchange between these systems would result in lower transaction costs of information exchange, increased operating efficiency and a higher quality of service due to fewer transaction mistakes and easier access to critical medical data. Additionally, most healthcare facilities still store patient information on paper-based formats. Therefore, every time paper-based data needs to be transferred to a different stakeholder, it is necessary that it is entered into the information system by hand, resulting in a huge operating inefficiency.

Walker *et al.* (2005) investigated what the net value of a fully implemented health care information exchange and interoperability (HIEI) system would be. This study weighed the estimated interoperability cost savings of the US health care domain against the estimated project costs of a full roll-out of a HIEI system. The study defined four levels of interoperability and estimated the net value of achieving each level. The levels are defined as follows:

Level 1: Non-electronic data. No use of IT to share information. This level represents the operational efficiency of the health care system prior to the introduction of IT and serves as *baseline* comparison for determining the benefits of the other levels.

Level 2: Machine transportable data. Transfer on non-standardized data via basic IT channels. Data cannot be manipulated by machines (e.g. exchange of scanned documents via fax or PDF files).

Level 3: Machine organizable data. Transfer of non-standardized data via structured messages. Requires mappings such that data conforming to different standards can be interpreted by each local system. Still requires transferred data to be verified due to the risk of imperfect mappings.

Level 4: Machine interpretable data. Transfer of standardized data via structured messages, allowing data to be transferred to and understood by all local systems.

Level 2 systems are already universally implemented amongst all health-care institutions, therefore requiring no costs of implementation. The costs of adopting level 3 and 4 were estimated by compiling various cost estimates for the sub-components of each level from different sources, such as established scientific studies, the US census bureau and expert-panel judgements (Walker *et al.*, 2005). The aggregate cost estimates of the HIEI implementations and their resulting net values are listed in Table C.

	Implementation, cumulative years 1–10	Steady state, annual starting year 11
Level 2		
Benefit	141.0	21.6
Cost	0.0	0.0
Net Value	141.0	21.6
Level 3		
Benefit	286	44.0
Cost	320	20.2
Net Value	–34.2	23.9
Level 4		
Benefit	613	94.3
Cost	276	16.5
Net Value	337	77.8

Table C: Estimated net value of deployment of HIEI systems, according to different levels of sophistication, in the US health care industry(in $Billions)(Walker *et al., 2005*).

The result of the study indicated that a nationwide adoption of level 4 HIEI system would result in an annual net gain of $77.8 billion after the initial implementation phase. This corresponds to approximately 5% of the annual US expenditures on health care.