How Will Ripple Effects of Financial Impact on Water Infrastructure be defined for the Future?

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Water, sewage, and other systems sector is the vital and essential infrastructure of the nation that provides critical services. These systems serve as the cornerstone of municipal systems, economical safety, various businesses, security, individuals and households, public health, government management, economic activity, and government operations of the nation.

While the country is focused on community vulnerability and the immediate health crises related to the COVID-19 pandemic these days, we also face long-term potential health crises associated with the water, sewage, and other systems sector.

In the era of a contagious disease or epidemic disease, the water infrastructure systems such as distribution pipelines, conveyance systems, water treatment plants, water storage tanks have made society dependent on the safe and sanitary water systems that are increasingly using an increasing amount of clean water sources. Therefore, our society is becoming reliant on water, which implies that disruption to water supply services and sustained contamination of water resources will result in bigger economic and societal losses.

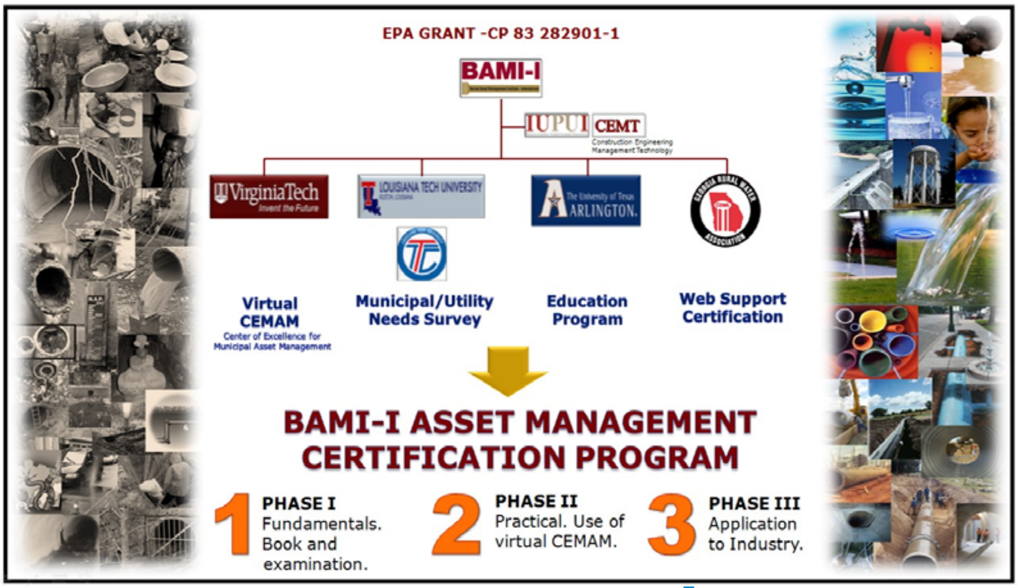
American Society of Civil Engineer's Report Card for Water Infrastructure for over two decades

Drinking Water		Wastewater	
2020	D	2020	D+
2017	D	2017	D+
2013	D	2013	D
2009	D-	2009	D-
2005	D-	2005	D-
2001	D	2001	D
1998	D	1998	D+

Figure 1. American Society of Civil Engineer's Report Card for Water Infrastructure for over two decades (Source: Figure created by the author)

Nevertheless, the most recent American Society of Civil Engineers (ASCE) infrastructure report card had already assigned a "D" to the drinking water infrastructure and a "D+" to the nation's wastewater infrastructure. Figure 1 shows the grades of the American Society of Civil Engineers' Report Card for water infrastructure for the last few decades. Since 1998, the grades have been near failing, averaging only Ds, due to current infrastructure conditions and investments that do not seem to have improved for over

Exposing students to as many events in the industry as possible is an important initiative



pleting their tasks. They gave great presentations in class. For most of the students, this was their first experience with an industry conference. It was encouraging to see the excitement and appreciation which they expressed. One of the students wrote: All in all, I got out of my comfort zone and talked to several companies and people within the construction industry. I obtained a lot of knowledge and information on the underground/utility sector of the construction industry. I really enjoyed the seminars that took place in the morning. I learned about HDD locators, current technology that geophysics are using, laws and codes that are used to identify and work with underground utilities, and safety within the underground construction scene. I also learned about polymer concrete and different materials that are being used to make pipes.

It was a rewarding trip for all parties involved. But we want to emphasize that this would not have happened without the support of industry companies. We would like to thank all of our sponsors for their generous support. We would also like to thank the Purdue CEM faculty and students for their encouragement and support of our initiatives. Going forward, UIT will continue to be committed to its mission. We hope to build deeper relationships between the industry and young students in more ways, such as lectures by professionals in the classroom, student observation at construction sites, and internships, to name a few.

CTAM 100 Overview of Asset Management

CTAM 200 Developing Asset Management Plan

CTAM 300 Managing Asset Management Plan

CTAM 400 Financing Asset Management Plan a decade. Water infrastructure report cards using the A to F school report card format provide a comprehensive assessment of current water infrastructure status and needs, and the grades are based on the eight criteria of capacity, condition, funding, future need, operation and maintenance, public safety, resilience, and innovation.

Taking these effects above into consideration, the insufficiency of capital investment of water infrastructures will cause financial impacts to our industries and communities, which means that we need to consider alternative plans and pay attention to the issue.

Given the fact that water service problems may cause the financial impact of dozens of billions each year, this fact has implications for the significance of a sustainable water supply's ability to enhance and support societal and economic value.

A well-organized plan associated with water, sewage, and other systems sector will demonstrate that managing appropriate investment strategies and taking appropriate financial actions can minimize the financial impact due to the inefficiency of water systems.

What interconnectedness of water sector is saying

Capital investment in the water sector financially affects our social system, oil and natural gas sector, electric power sector, environment, administrative and support services, transportation, and so on. In other words, efficient capital investment of water infrastructure can have an affirmative financial impact and societal influence. The capital investment caused by the financial impact of affirmative action will greatly affect one or more economic systems. Figure 2 shows the interconnected sectors that are composed of critical infrastructure such as oil, electric power, natural gas, telecom, water, transportation, and so on.

If there is a lack of financial investment in the water, sewage, and other systems sector, it will gradually affect economic impacts to one or more sectors. A direct financial impact of water services would be the direct change of productions and needs due to tangible lack of capital investment for water infrastructure, and an indirect financial impact would be the change other infrastructures suffer due to the lack of capital investment for water infrastructure based on infrastructure relationships.

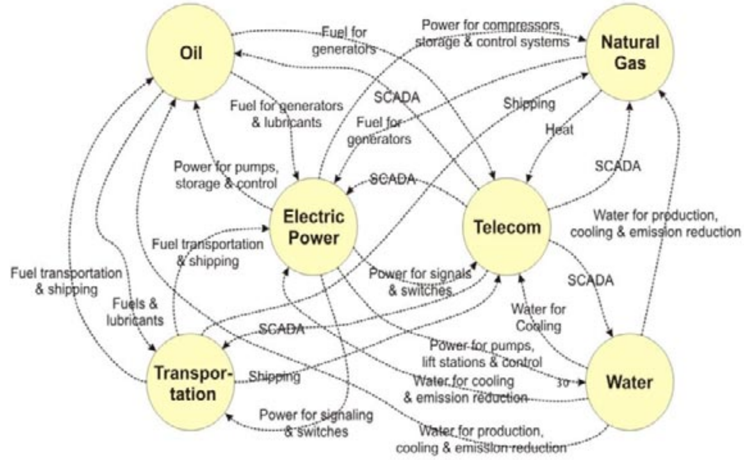


Figure 2. Interconnected Sectors Associated with Critical Infrastructures (Source: After Rinaldi et al. 2001)

The technical coefficient matrix and the input–output model

To measure ripple effects that predict the effectiveness of water infrastructure capital investment, the technical coefficient matrix and input–output model have been used. It shows how to connect one or more economic systems and it is a model for the interconnectivity between over 400 sectors. The used data has been released as part of the 2018 comprehensive update and revised for the 2021 annual update from the Bureau of Economic Analysis. It is used the detail-level make and use tables from the input-output accounts for the years 2012.The data will represent industrial-economic interconnectedness and interdependencies across all other industries in the U.S. economic system. The definitions of each element of the normalized make matrix and the normalized use matrix can be summarized as follows:

> Water needs essential ingredients from diverse sectors

- Normalized make matrix (V^): The amounts of the different commodities in the columns produced by the industries in the rows
- Normalized use matrix (U^): The amounts of the different commodities in the rows consumed by the industries in the columns
- Total industry output (X): The value of all commodities produced by a particular industry
- Total commodity output (Y): The value of all the intermediate industry consumptions and exogenous demands
- Exogenous commodity demand (e): The amount of commodity uses other than the intermediate consumptions by industries
- Value added (zT): The amount of industry inputs other than commodities

The overall procedure for technical coefficient matrix

Figure 3 shows the key point diagram for the interconnectedness matrix. Above all, the first equation shows that the product of the normalized make matrix and the normalized use matrix is the input-output model A matrix. The second equation shows the correlation between the final consumption of industry output, the normalized make matrix, and the exogenous commodity demand. The third equation shows the correlations between the total industry output, the normalized make matrix, and the total commodity output. The fourth equation shows the correlations between the total commodity output, the normalized make matrix, the total industry output, and the exogenous commodity demand. The fifth equation shows the correlations between the normalized make matrix, the total commodity output, the total industry output, the normalized use matrix, and the exogenous commodity demand. The sixth equation shows the correlations between the total industry output, the input-output model A matrix, and the final consumption of the industry output.

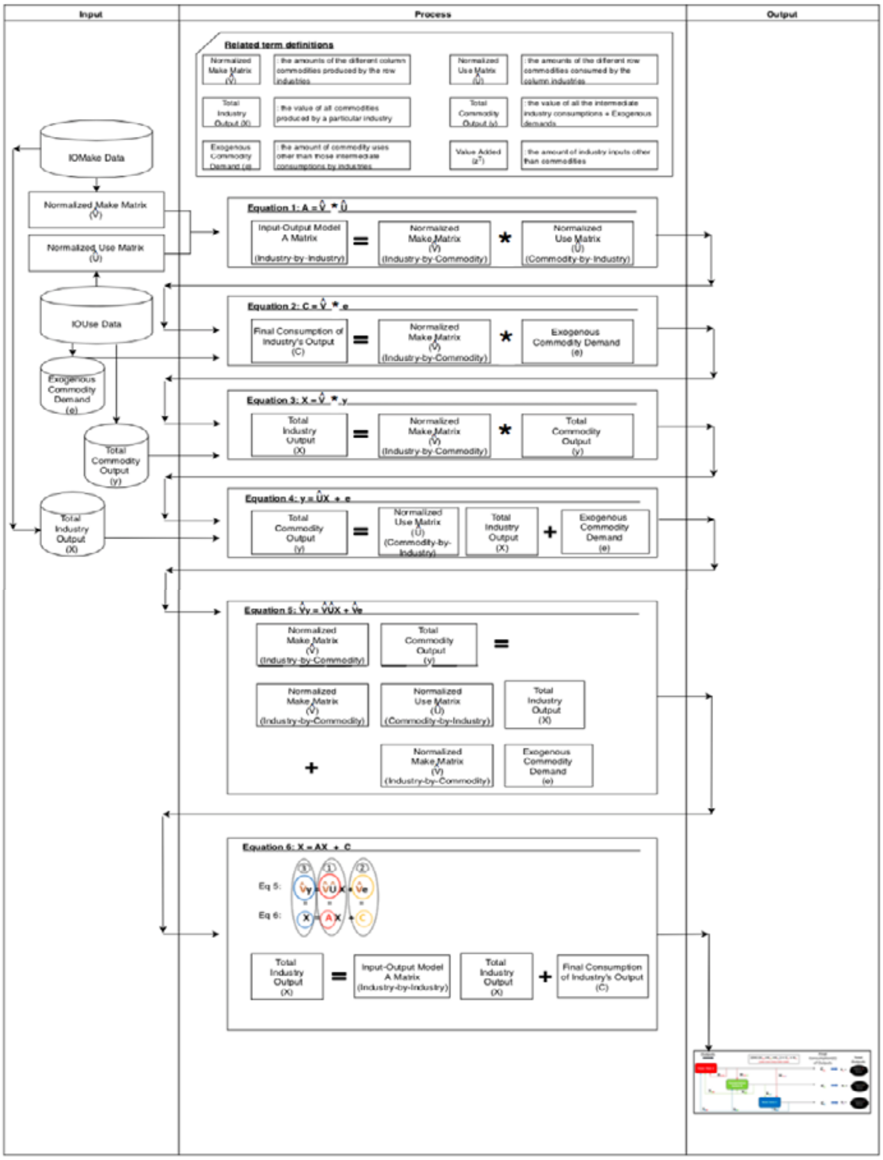


Figure 3. The Key Point Diagram for Interconnectedness Matrix (Source: Figure created by the author)

The historical input-output data of the make and use matrices for the years 2012 is utilized to evaluate the ripple effects regarding the effectiveness of water infrastructure capital investment. To measure the economic benefit's contribution from one sector to another sector, the interdependency matrix for economic benefits is created by the technical coefficient matrix and the vector of the as-planned productions of a sector. This is a year-based assessment, and it has been defined as the values of interconnectedness across over 400 infrastructures for the years 2012. The interconnectedness matrix in one year has 164,025 interconnectedness relationships that represent the values of interconnectedness on interrelated industries, respectively.

Value of interconnectedness in terms of water, sewage and other systems

Figure 4 shows the value of interconnectedness in terms of the demand-side of water, sewage and other systems (IO code: 221300) sector for the year 2012. It can be interpreted that the overall trends of the value of interconnectedness for the year 2012 were somewhat fluctuant when comparing to the past year.

The highest relationships with the water, sewage and other systems in the interconnectedness matrix on the demand-side was IO code 2123A0 (Other non-metallic mineral mining and quarrying) in the year 2012. The second most related sector on the demand-side was IO code 325120 (Industrial gas manufacturing). The third most related sector on the demand-side was IO code 493000 (Warehousing and storage). The fourth most related sector on the demand-side was IO code 811200 (Electronic and precision equipment repair and maintenance). The fifth most related sector on the demand-side was IO code 325180 (Other basic inorganic chemical manufacturing).

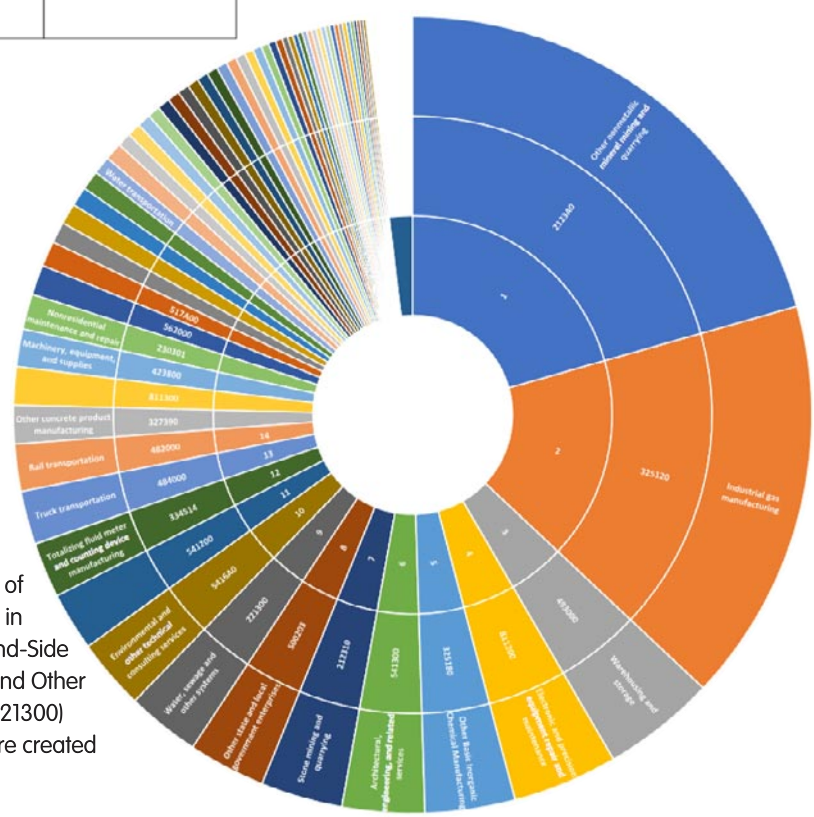


Figure 4. The Value of Interconnectedness in Terms of the Demand-Side of Water, Sewage and Other Systems (IO code: 221300) sector (Source: Figure created by the author)

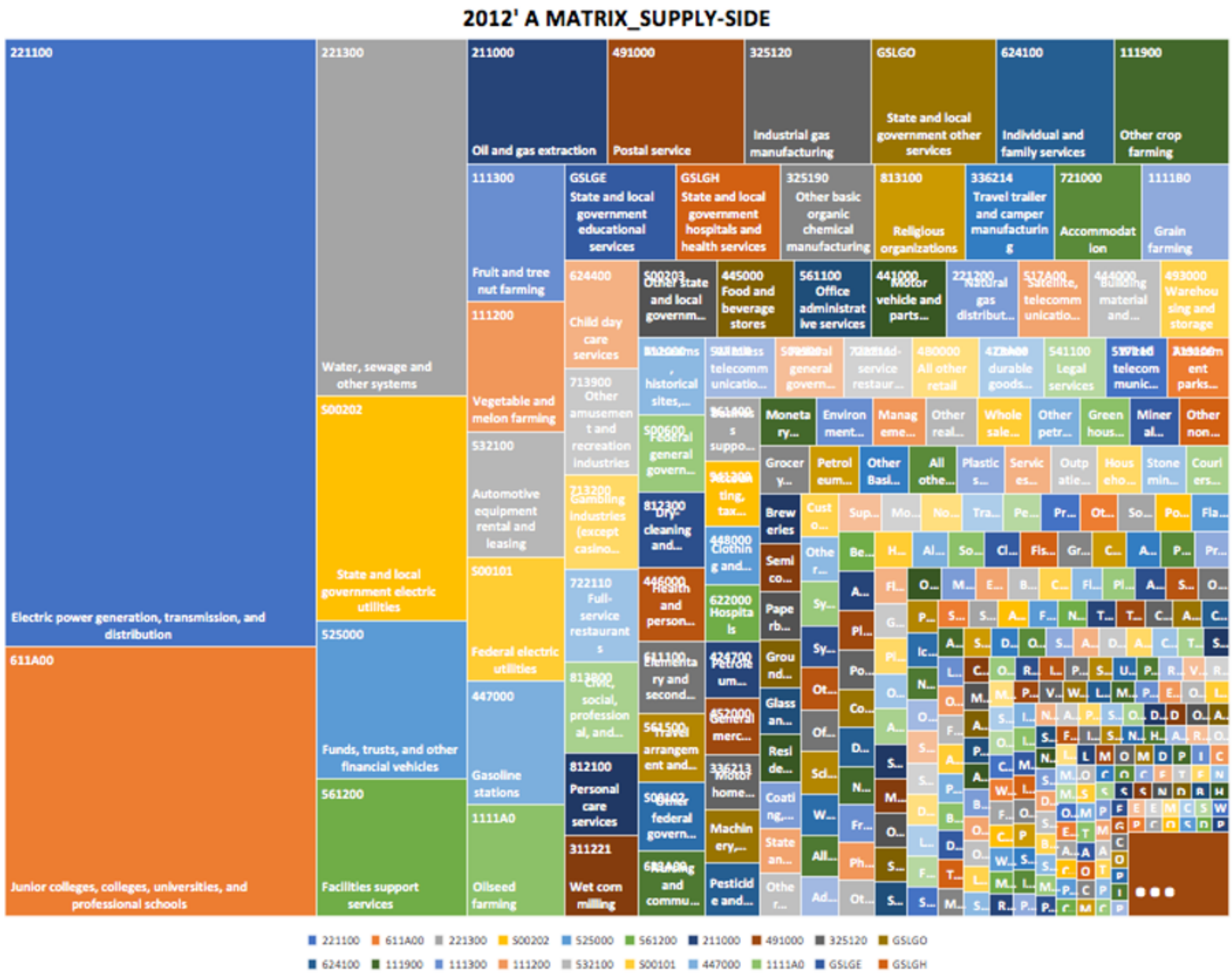


Figure 5. The Value of Interconnectedness in Terms of the Supply-Side of Water, Sewage and Other Systems (IO code: 221300) sector (Source: Figure created by the author)

On the flip side, Figure 5 shows the value of interconnectedness in terms of the supply-side of water, sewage and other systems (IO code: 221300) sector for the year 2012. The highest relationships with the water, sewage and other systems in the interconnectedness matrix on the supply-side was IO code 221100 (Electric power generation, transmission, and distribution) in the year 2012. The second most related sector on the demand-side was IO code 611A00 (Junior colleges, colleges, universities, and professional schools). The third most related sector on the demand-side was IO code 221300 (Water, sewage and other systems). The fourth most related sector on the demand-side was IO code 500202 (State and local government electric utilities). The fifth most related sector on the demand-side was IO code 525000 (Funds, trusts, and other financial vehicles).

Value of interdependence in terms of water, sewage and other systems

Water needs the essential ingredients from diverse sectors. Figure 6 shows the value of interdependence in terms of the demand-side of water, sewage and other systems (IO code: 221300) sector for the year 2012. It shows the most water-intensive sectors for water, sewage and other systems sector as suppliers. Water indicates a demander. Industrial gas manufacturing (325120) is the largest provider for the water sector in the United States. In other words, the highest relationship with the water, sewage and other systems in the interdependency matrix on the demand-side was IO code

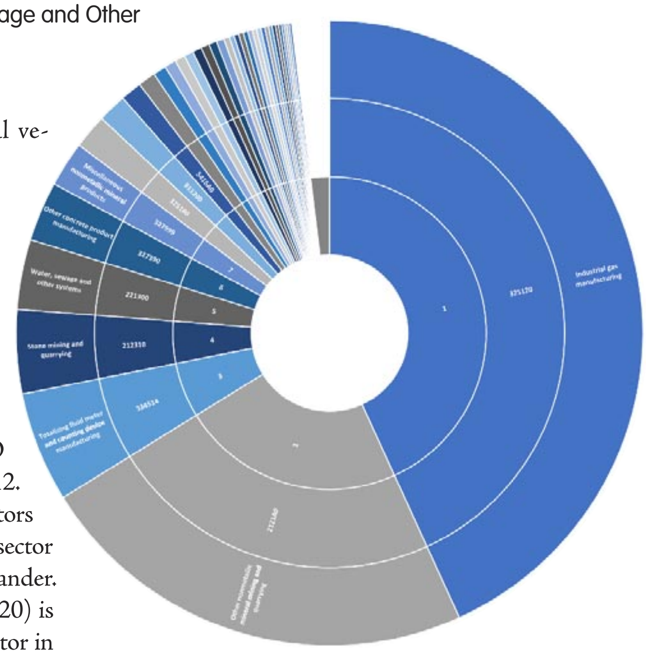


Figure 6. The Value of Interdependence in Terms of the Demand-Side of Water, Sewage and Other Systems (IO code: 221300) sector (Source: Figure created by the author)

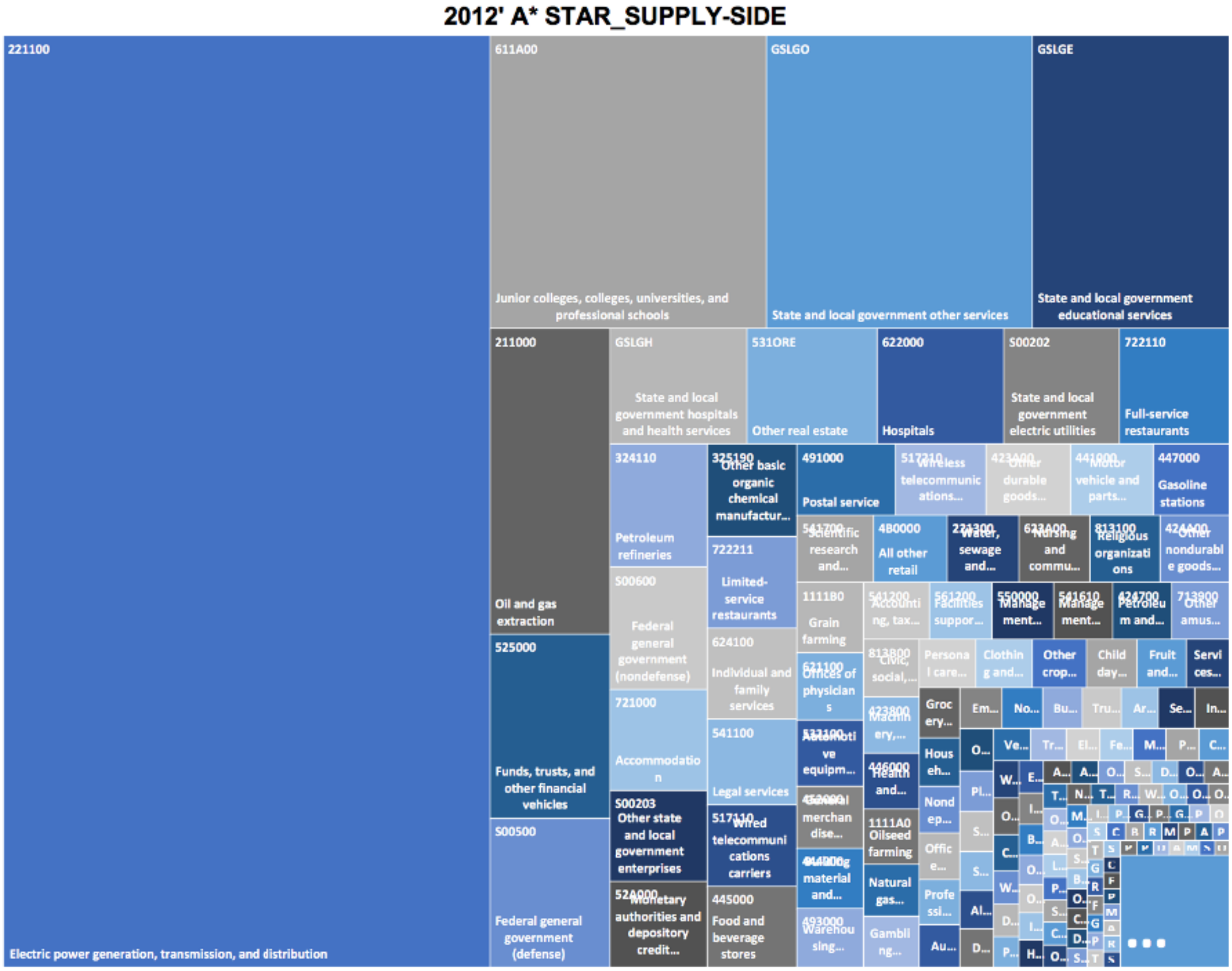


Figure 7. The Value of Interdependence in Terms of the Supply-Side of Water, Sewage and Other Systems (IO code: 221300) sector (Source: Figure created by the author)

325120 (Industrial gas manufacturing). The second-largest relationship with the water, sewage and other systems in the interdependency matrix on the demand-side was IO code 2123A0 (Other nonmetallic mineral mining and quarrying). The third-largest relationship with the water, sewage and other systems in the interdependency matrix on the demand-side was IO code (Totalizing fluid meter and counting device manufacturing).

On the other hand, water can be the vital ingredient that fuels all other sectors. Figure 7 shows the value of interdependence in terms of the supply-side of water, sewage and other systems sector for the year 2012. It shows the most water-reliant sectors for water, sewage and other systems sector as demanders. Water indicates a supplier. Electric power generation, transmission, and distribution (221100) is the largest user of water resources in the United States. In other words, the highest relationship with the water, sewage and other systems in the interdependency matrix on the supply-side was IO code 221100 (Electric power generation, transmission, and distribution) in the year 2012. The second-largest relationship with the water, sewage and other systems in the interdependency matrix on the supply-side was IO code 611A00 (Junior colleges, colleges, universities, and professional schools). The third-largest relationship with the water, sewage and other systems in the interdependency matrix on the supply-side was IO code GSLGO (State and local government other services).

> Water can be the vital ingredient that fuels all other sectors

There is a possibility that people don't associate a glass of beer or a gallon of petroleum with their water supplies. However, virtually all end-user products rely on water resources to varying degrees.

Significance of ripple effects of financial impact on water infrastructure

Municipal governments have owned and controlled 85 percent of water utilities and 54 percent of sewer utilities. However, most fall under the public works department or utility department (The American Public Works Association (APWA)). APWA pointed out that municipal governments cannot resolve the need for additional federal support and funding, and they may only offer a limited plan of what communities can afford. As federal aid for water infrastructure capital needs has declined (from 31 percent in 1977 to 4 percent in 2017), the expenditure of regional and state has accounted for a much larger share, affecting financial operations and soundness adversely. Increased challenges and risks of the water, sewage, and other systems (IO code: 221300) sector due to the lack of capital investment in the water infrastructures ultimately lead to increased physical, societal, and economic risks. APWA insists that the Environmental Protection Agency should promptly request from Congress and Congress should provide a considerable amount of money in federal funding for capital investment in water infrastructure.

Taking all these things into consideration, the ripple effects of the financial impact on water infrastructure show the economic benefits of additional federal support in water infrastructure between interdependent sectors within the economic system to facilitate the federal government's share of capital investment. This approach of predicting the ripple effects from the additional capital investment in terms of the water infrastructures will help in creating a paradigm shift in the current state of practice.

> Virtually all end-user products rely on water resources to varying degrees

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Kevin KwangHyuk Im is currently Ph.D. candidate in Construction Engineering and Management at the Lyles School of Civil Engineering, Purdue University. His academic background has focused on interdisciplinary research spanning the traditional boundaries between construction engineering and business administration.