Temporary urban regeneration: a systematic approach for a multi-system life cycle assessment

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Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
in
Environmental Design and Planning

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December 19th, 2022
Blacksburg, VA.

Keywords: Urban Regeneration, Temporary Urbanism, Vacant Lands, Intermodal Shipping Containers, Empty Container Repositioning, Dry Ports, Modular Structures, Life Cycle Assessment, Multi-system Assessment.

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Abstract

This research attempts to evaluate temporary urban regeneration potential by integrating two systems that make up an interim intervention which addresses an observed problem. The research proposes a systematic approach for a multi-system life cycle assessment model which lays out the process of working with two separate systems to provide a pathway for temporary urban development strategies. To achieve this, the research starts with identifying parameters of temporary urban regeneration through a systematic review of the literature. Key parameters are categorized based on objectives, indicators, as well as, physical characteristics of the literature explored case studies. Then, the findings are utilized to guide the proposed model of connecting two given systems to assess their joint impacts on a temporary urban regeneration system. The proposed MSLCA framework utilizes a holistic modeling structure with a process to integrate and analyze separate systems and quantify results for overall sustainability performance. Finally, the model is used to evaluate a case study involving two systems that address observed problems and provide urban services. The results explore the environmental impacts of the proposed intervention and highlight the effects of individual components on both systems. Through the implementation of the model, decisions on temporary urban intervention are guided by hotspots in the results. The findings reveal an opportunity for future research to expand the model's application to other processes and further its scope beyond environmental indicators. Subsequent studies can investigate opportunities for a holistic approach that includes economic and social aspects.

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General Audience Abstract

The way we live in cities is heavily influenced by how they are planned. Improvident city planning could deny residents opportunities to enjoy some basic urban amenities. These problems could be self-induced as they are often a result of planning, policies, or personal habits and choice. Planners, urban designers, and regulators are constantly experimenting with different tools of urban regeneration to rediscover genuine urban experiences. This research sets out to investigate opportunities for temporary urban interventions on vacant lands in the city of Riyadh through repurposing idle shipping containers as a tool. This is to address the issues of a lack of urban services within residential subdivisions in the city, the high prevalence of vacant lands, and a wide availability of decommissioned shipping containers.

The use of shipping containers for non-cargo purposes has seen an increased interest among architects and designers for their versatility and accessibility. Empty container accumulation is often a result of an unbalanced trading system which is mainly an issue of import-based countries. Therefore, the upcycling potential of intermodal containers can extend their life cycles and take advantage of their structure. It also maximizes the environmental returns of their raw materials. Through such processes of circular economy, potential waste objects can be repurposed as resources into usable structures and thus avoids the use and extraction of new raw materials. It is generally thought that the repurposing of shipping containers into building structures introduces environmental advantages when compared to traditional construction. Similarly, vacant lands are a valuable and well-established resource that can provide the setting for temporary urban interventions.

Finding a joint productive use of these systems is at the center of this research as it attempts to assess the urban regeneration value of their merged utility during their idle stage. This helps address a key challenge that most urban area suffers from which is the lack of easily accessible and timely deployable temporary urban intervention to serve a particular use. This research aims to create a model that evaluates the lifecycles of temporary uses based on the joint intersection of contributing systems. The proposed Multi-System Life Cycle Assessment (MSLCA) model is to

be applied to assess temporary urban regeneration interventions and help make decisions regarding appropriate approaches. The goal of the model is to propose a value-based approach based on characteristics from two systems. The resulting MSLCA model answers questions on how to apply LCA processes to a transitional intervention with new processes. In doing so, it highlights parameters for systems integration and processes for planning appropriate scenarios for urban interventions. It also highlights the need for unique system boundaries and specifies approaches for system assessment and interpretation. Finally, it provides broader impact categories beyond environmental impacts to consider specific economic and social indicators.

Acknowledgements

First of all, I would like to offer my special thanks to Dr. Georg Reichard for his guidance and assistance at every stage of my research; without him, I would have not been able to complete this endeavor. I am also grateful to my committee of Professor David Bieri, Professor Elizabeth Grant, and Professor Mintai Kim for their valuable contributions and insightful suggestions.

Accomplishing this could not have been possible without the help of my family. Special thanks to my parents for their constant encouragement and motivation. I am deeply indebted to my siblings for their invaluable advice, continuous support, and for allowing me time away from home. I am also profoundly grateful to Diana Blair for her unwavering support and belief in me.

Finally, I would like to express my sincere gratitude to the Saudi Arabian Ministry of Higher Education, the Saudi Arabian Cultural Mission (SACM), and King Said University for providing financial support without which this research would not have been possible.

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Chapter 1 - Introduction

1.1. Background

The urban environment we live in today is in a constant state of change. In a few decades, 75% of the world's population is expected to live in cities; 50 of which will exceed 10 million in population. Globally, it is estimated that 5 million people move to cities every month (Glaeser 2012). One factor driving such growth is the rise of the middle class in the developing world. In fact, it is estimated that in Asia alone the middle class has more than tripled in the last decade to 1.7 billion (Mahbubani 2013). By 2030, it is estimated that 3 billion more people will join the middle class around the world. With expanding urban environments around the world, cities are facing new sets of challenges which demand a need for creative solutions.

The urban environment clusters people and systems together. These environments are characterized by population density and vast human interactions. Urban environments encompass cities, towns, and settlements identified by their exchanges. Inhabitants of these environments require services and resources that deliver three fundamental qualities: utility, durability, and sustainability. Consequently, urban environments should accommodate the needs of users and processes of nature through both structurally and functionally sound systems that consider sustainability as a critical factor of urban wellbeing. Creative urban solutions play a key role in approaching existing problems by refocusing on issues of the challenges at hand.

1.1.1. The city of Riyadh, Saudi Arabia

Over the past decades, Riyadh has witnessed dramatic changes due to the rapid urbanization that it went through. The city grew from a small village characterized by a unique compact urban fabric with courtyard housing, to a metropolitan region housing 25% of the country's population (Akbar 2002). Riyadh observed an accelerated pattern of rapid growth that transformed the once small village of around 40,000 in the 1940s to a projection, by the Central Department of Statistics and Information, of exceeding the 8 million mark by 2024 according to the Saudi Central Department of Statistics and Information (CDSI). To accommodate the increasing migration, the city went through three development plans all focused on low-density, single-use zoning connected by roadways (Alsaiari 2010). This has enabled a fragmented urban landscape characterized by vacant White-land as its distinguishing feature (Figure 1).

Figure 1. Arial image of Riyadh shows the prevalence of vacant White-lands (alriyadh.com)

Riyadh planning model

The urban landscape of Riyadh provides an important topic to investigate. Its position as the Kingdom's capital and the home for most national institutions, allowed it to enjoy rapid development. Riyadh benefitted from social, economic, and institutional attention which attributed to the acceleration of its development. The first comprehensive urban plan of Riyadh was commissioned by the Greek firm Doxiadis Associates in 1971 (Figure 2). The plan was intended to mainly manage the unplanned growth of the city. Although some growth boundaries were introduced, the plan focused on spreading growth outward rather than containing it within existing city limits. The design introduced a North-South axis parallel to the boundaries of the natural landscape. The plan consisted of a 2x2 kilometers modular units that can be duplicated within the growth boundaries to channel growth. The plan encouraged large-scale sprawl characterized by low rise and low-density development (Saleh 2004).

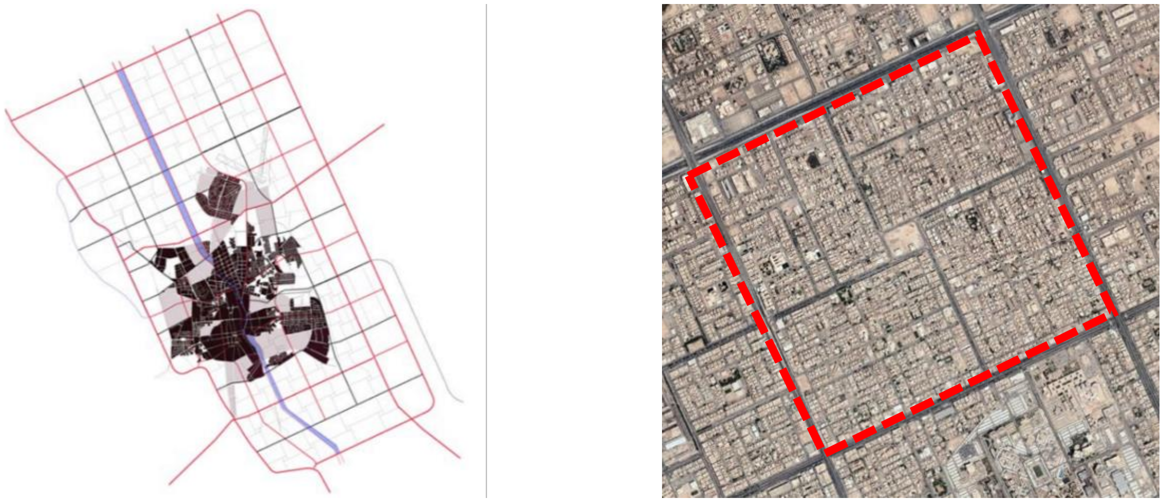

Figure 2. Riyadh's first master plan which introduced modular units alongside arterial corridors

The plan also enabled several players that facilitated the city's rapid growth. These players highlight the traditional significance of Saudi Arabia and speak to the cultural importance of Riyadh. The first player is the social patterns of urban living in the city in which multigenerational living is widely common. It is a tradition for adult children as they start their own families to live within proximity to their parents (Alskait 1993). Consequently, most housing units in Riyadh that were built to "maintain stronger social bonds", created a housing pattern that resulted in fragmented widespread urban sprawl (Mubarak 2004). The second player is the land grants program that guarantees a residential plot of land to each family on which they can construct their homes. This common governmental practice was put to ensure equal access to housing opportunities and enhance the housing market in the city. Most lots granted through the program are usually at the edge of the city, which became the city's way to channel growth. Recipients tend to retain the land until the value increases, thus contributing to the number of vacant lands (Al-Hathloul 2004). The third player is another approach by the Saudi government to enhance the housing market. The Real Estate Development Fund (REDF) provides long-term, interest-free loans for citizens to help them build their homes. The program functioned separately from the land grant program, and therefore, candidates who bought lots themselves are also eligible to receive loans.

Although these two programs have been terminated and replaced by new housing programs, their effects on land vacancies still persist. The downside of these programs on the urban level was that since they did not obligate beneficiaries to develop their lots causing widespread of vacant lands in the city. Most recipients chose to either wait until sufficient growth reaches the area or hold on to their lots enough time for it to appreciate in value only to sell it to make a decent profit (Al-Hathloul 2004). Once a lot enters the market, it often changes hands from one broker to another raising its price with each transaction. By the time a lot reaches the end-user, the price gets inflated resulting in socio-economic segregation within the city.

Riyadh growth model

Most efforts to address these issues were hindered by unexpected population growth. Many scholars make the point that "Riyadh's population growth over the past fifty years does not fit a constant simple exponential growth model of natural populations" (Middleton 2009). Therefore, urban processes failed to prepare for such growth. The constant waves of migration to the city resulted in high levels of housing shortages in existing areas of development. This pushed the city to expand outward beyond its boundaries. This expansion was not planned by the city's master plan, and as a result, had an immense impact on the city's urban model. Riyadh's planning model and the execution of that model present some of the urban pitfalls that the city still suffers from today. The city's master plan shows a lack of focus on creating social and public spaces in the city (Middleton 2009). Many relate the city's plan to the state of social life in the city, "There is no consideration of families social life within the design strategies, which may reflect preconceptions of the society or an absence of knowledge specific to the social and cultural context of Saudi Arabian life" (Middleton 2009). This was exacerbated by the omission of open public spaces and recreation areas, especially within residential neighborhood limits.

Several studies make the connection that the deficient implementation of the planning unit established by Doxiadis is what enabled services, open spaces, and the historically pedestrian-oriented nature of the city to disappear. Based on the city's master plan, commercial developments should only occur on the boundary edge of the city planning unit (Doxiadis, 1971). This relegated all activities to the edges of neighborhoods causing an oversupply of commercial activities on the boundaries and a lack of comparable services in the centers. This segregation of uses enabled edges of the modular neighborhood units to develop at differing rates than the center. This pushed the city to grow at an accelerated rate along its planned growth axis while neighborhood centers were not mature yet. This left large areas of inner lands undeveloped and further hindered the centers to establish an active community lifestyle. This also lowered the economic viability of establishing commercial and cultural facilities in the center. Consequently, this plan has created an urban model that is vibrant along the perimeter while fragmented and underserved in the center (Figure 3).

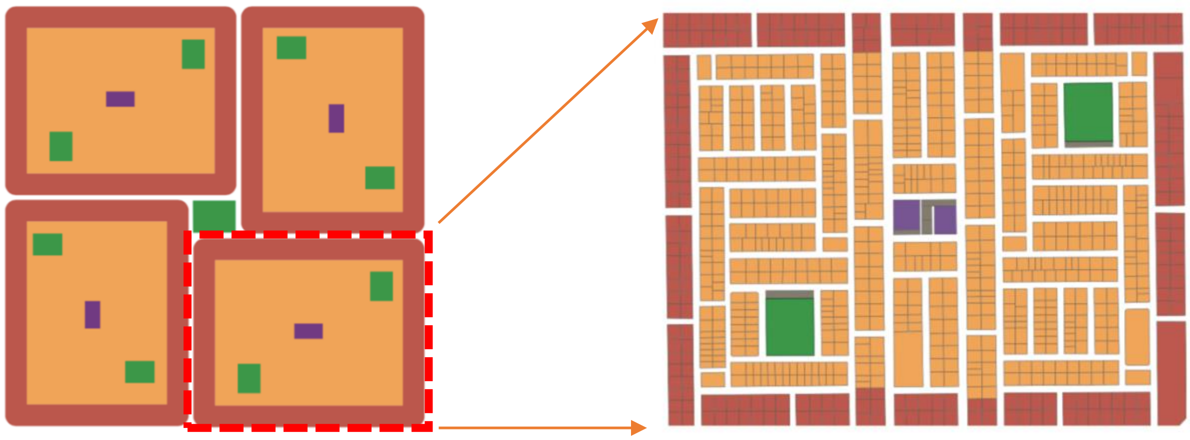

Figure 3. Zoning diagram of Doxiadis planning module showing the distribution of land uses - commercial (red), residential (yellow), recreational (green), and service (purple).

1.1.2. Vacant lands

Vacant lands are plots of land that are not developed and show no clear plans for development. They can be empty lands or plots with abandoned structures and are often considered an obstacle to urban development (Raco and Henderson 2006). At the local level, Faisal Mubarak claims that the current model of land subdivision development increases the prevalence of vacant lands (Mubarak 2004). Real estate brokers who develop these subdivisions are mainly interested in quick financial returns. These subdivisions attract two types of investors. The first type of investors are builders who are interested in providing a residential product that can be built quickly and at a minimum cost. The result is duplicate low-quality concrete boxes. The second type of investors are real estate brokers who use these subdivisions as an investment tool without any specific proposal for development (Mubarak 2004). This model produces an unattractive urban environment that is characterized by urban developments that provide minimal amounts of social and environmental standards (Abdulaal 2012). This discourages newcomers to these types of subdivisions leaving large swaths of land vacant. A report by the Riyadh Development Authority indicates that “Undeveloped “white lands” within the growth boundary of 2030 comprise approximately 50 percent of the total land area” (ADA, 2010). Additionally, the public sector has made no tangible efforts to slow down unjustified urban growth or to ensure the delivery of public urban goods such as parks and public spaces.

White lands

White land is an urban term used locally to describe vacant urban subdivisions without any specific proposal for development. Typically, lands are used as an investment tool. Many in the Kingdom consider land as a form of asset and a secure tool to preserve capital. The rapid growth of the city meant high returns on capital invested in vacant lands. This fueled a speculative white land market. In 2015, municipal estimates suggest that 40% of urban land in Riyadh is underdeveloped (Figure 4). Many blame white lands for increasing the cost of living in the city. In many cases, the cost of land in Riyadh can match or exceed the construction costs of a given project. It is important to note that urban subdivisions are a large municipal investment, and underutilized ones can be considered a significant loss to that investment. The lower the number of people they serve the more expensive they become to build and maintain. Moreover, underutilization brings about decentralization, which spreads the urban fabric more thinly, and consequently, provides less access to socialization. Several studies suggest that living in sprawl and fragmented urban fabric lower opportunities for socialization (Al-Hathloul 1981). It can be observed that the areas in dire need of services are areas of lower density and high prevalence of White-lands. These issues relate to the planning model of the city that focuses on the separation of uses. This separation, combined with the local culture in the city, enables strict division between private and public spaces. In recent years, the nature of public space in Riyadh is starting to see some changes in reflection to the changing production, consumption, and management powers in society.

Figure 4. Arial images show patches of vacant lands alongside major highways in Riyadh (alriyadh.com)

Vacant land development

The development of underutilized properties can bring positive market attributes and turn them into productive assets (Davis 2002). Improving the quality of the urban environment has an immense benefit to the overall quality of life. In general, vacant lands are known for decreasing property value and for discouraging development in surrounding areas. On the other hand, the existence of vacant land can encourage opportunities for urban transformation (Goldstein et al. 2001). Realizing the value of vacant land can help determine the potential for its development. Additionally, understanding the factors that encourage landowners to retain landownership for a period of time is key to encouraging vacant land development. Several studies have concluded that determining the value of vacant land can differ based on the utility brought by its use (Titman 1985). Understanding the local circumstances that guide the use of vacant lands can help in the valuation. Research refers to two main factors to successful land development (De Sousa et al. 2009). First, is the economic incentive of developing the land weighted against potential liabilities. Second, is the public policy regarding vacant land development. On the other hand, there are several factors that hinder vacant land development. These include environmental and socio-economic factors (BenDor et al. 2011).

Environmental concerns of land development

The main concern with the environmental benefit of land development is the remediation of the land. The development of land can bring about productive natural resources to the site. This revitalization process can reverse a site's environmental decline (Wang et al. 2011). Additionally, over its lifetime, the development of land can help reduce greenhouse gas emissions. By bringing services to an urban area, average vehicle mile traveled can be reduced by 20%-40% (Mashayekh et al. 2012). This is a major saving that can contribute directly to air and environmental quality.

Land development can also increase urban density. Encouraging high-density development can discourage urban sprawl. Developing existing infrastructure reduces the need for further urban sprawl. It is also recognized that higher urban density can minimize storm water runoff and reduce urban heat island effect. The phenomena of heat islands pertain to the differences in temperature between built and natural areas. The open undeveloped areas can absorb and retain heat which can increase the surrounding by up to 10 degrees Fahrenheit (Paull 2008).

Socio-economic concerns of land development

Reinforcing the social aspects of communities is at the center of sustainable urban regeneration. Land development can improve the quality of life and promote users' well-being. Successful land development strives to achieve long-term goals of community service. Vacant land development is considered to be an opportunity for user integration and community involvement. By implementing practical strategies of community engagement, land development efforts can provide more tailored urban spaces for users. These strategies can address issues of safety, public health, and local culture.

Stakeholders can also play a major role in guiding decisions and determining the value of vacant land and its development. They represent those who could be affected, directly or indirectly, by vacant land and its development (Cundy et al. 2013). Stakeholders can be categorized into five groups (Hou 2016). These include primary, institutional, intra-organizational, local community, and working party stakeholders. The involvement of all these groups influences the approach with which vacant lands can be developed. They also can influence the uses and activities that can be accommodated on vacant lands. Creative uses are most likely to occur in a temporary space (Taylor 2008). Any form of occupancy serves a social dimension. The social dimension of temporary space pertains to unofficial activities that users engage in a public space (Franck and Stevens 2006). The value assigned to public open space in dense urban areas cannot be overlooked.

Barriers to land development

Most types of urban development are perceived to be beneficial to a community, however, there are several barriers to vacant land development. A number of studies suggest that land location is key in determining the success of land development. Alberto Longo studied the characteristics that enable and discourage vacant land development. The research found that lands that are located in more thriving areas are more likely to be developed than lands located in less prosperous areas (Longo and Campbell 2007). Locations that are within proximity to better urban services and appropriate infrastructure tend to develop faster the less served areas (Lange and McNeil 2004). Other barriers to land development include low connectivity, low urban density, and lack of community support (Siebielec et al. 2012).

1.1.3. Urban sustainability

A sustainable urban system is one that defines practices that contribute to the wellbeing of users and the environment. Such sustainable character is better understood in terms of its functions, operations, and exchanges. Conventional urban systems tend to shift environmental burdens to the larger environment with minimal regard to relationships between built and natural systems (Hough 2002). To manage these relationships, local municipalities can bridge better communication networks for data with entities and organizations to effectively coordinate solutions. With broad involvement, ideas for dealing with urban challenges can help guide new solutions and set regulatory tools. To better bring these ideas to functional solutions that reflect the local needs, site-specific challenges can be approached through a rethinking agenda that involve all systems. Some relevant concepts include:

Thinking in systems

Systems that neglect urban sustainability produce problematic patterns. Often times these problems are a consequence of system structures rather than a result of one factor or event. System structures correlate and consequently generate valuable feedback loops. Thinking in systems in an urban setting requires a deeper understanding of how these structures work, a thorough comprehension of their web of interactions, and a capacity to avoid any traps they may generate. To deal with the complications of current urban systems, a transparent approach that brings urban processes to the surface is beneficial. Making processes visible can be achieved through a sustainably configured layout of assessments to meet objectives of transcending environmentally friendly solutions. Such a layout can highlight invisible system inefficiencies with the potential for providing new sustainable alternatives. In applying systematic thinking to urban issues, it is key to understand systems' leverage points and highlight their impacts on sustainability (Meadows 2008). To put sustainability at the core of an urban system, understanding the influence of these points on systems structure is useful in defining sustainable solutions. Donella Meadow introduces this concept of Systems thinking helps identify the root cause of any observed problem while considering the big picture (Figure 5). In reacting to this concept, a holistic urban sustainability approach can consider interdisciplinary actions through two major themes. The first is circular urbanism which enables sustainable ideas of rethinking systems at play to improve efficiency and minimize waste. The second is ecological urbanism which emphasizes the value of the natural system to enable a set of responsible practices for coherent and sustainable developments.

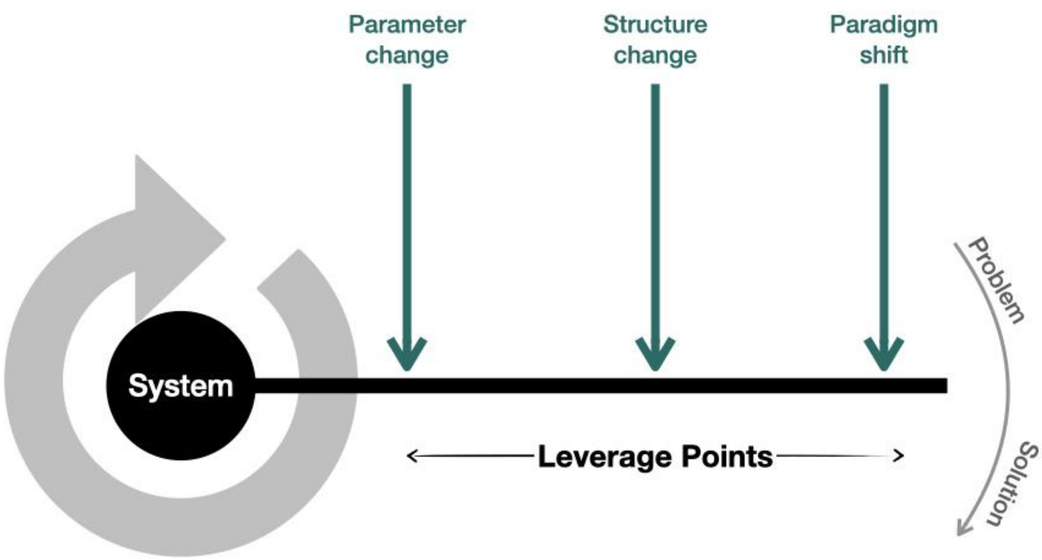

Figure 5. Donella Meadows leverage points for places to intervene in solving a problem in a system

Circular urbanism

It focuses on the process of achieving mutual urban prosperity across ecological and economic cycles (McDonough and Braungart 2013). The concept aims at keeping urban processes in continuous cycles (Figure 6). One cycle's waste is another's resource. This approach celebrates the abundance of diverse systems which enables the functionality of all systems. Circular urbanism encourages design ideas where materials are borrowed from one process and recycled in another. This approach inspires a new way of thinking where assets from one system can move to another in cycles of sustainable urban progressions. Urban systems, like most natural systems, occur in processes of progression that operate separately and linearly. This renders most processes irreversible, therefore, for urban progression to be sustainable it helps to understand urban structures and draw connections among systems at play. Consequently, current urban challenges need to be explored through cyclic systems as part of the overall natural, economic, social, and legislative domains.

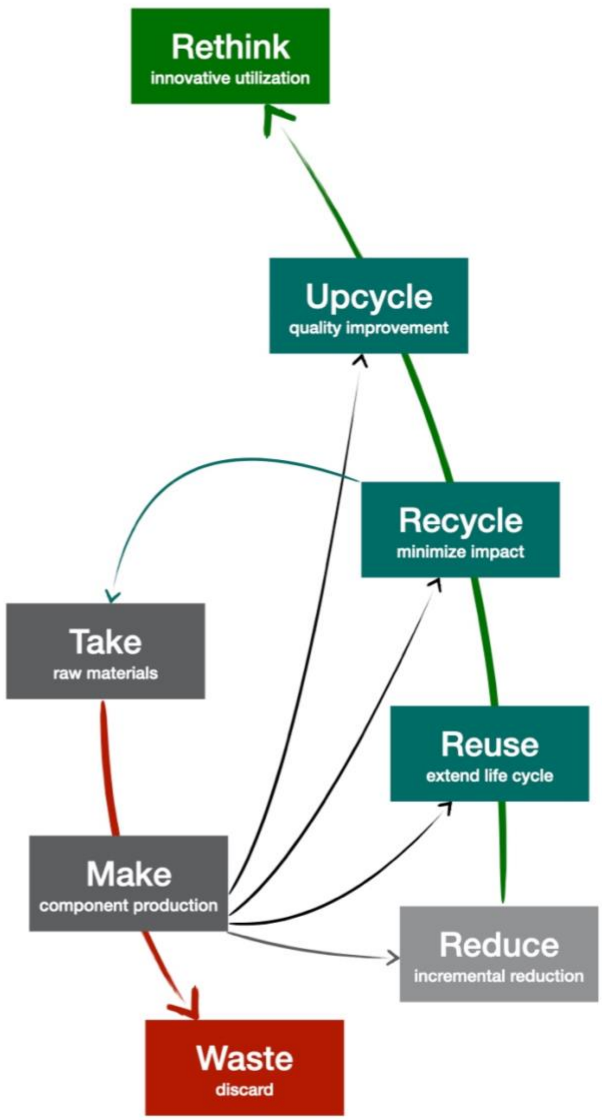

Figure 6. Circular approach for matter movement throughout a given system

Cradle to cradle

The industrial economy has undervalued the price of the environment through the usage of highly capable materials that once they serve their purpose get discarded. The concept of cradle to cradle advocates for the adoption of natural processes in industrial systems by leveraging circular material metabolism (McDonough and Braungart 2010). It aims to bring technical cycles of industrial systems and biological cycles of natural systems closer together to utilize them as assets. By considering nature's design principles, industrial systems can be encouraged to produce processes for technical metabolism for the circulation of organic and technical materials. By exploring means to redirect materials from systems interactions, new waste free cycles can be created for the mutual benefit of all systems.

1.1.4. Urban regeneration

Urban regeneration can be defined as "a comprehensive and integrated vision and action which leads to the resolution of urban problems and which seeks to bring about a lasting improvement in the economic, physical, social and environmental conditions of an area that has been subject to change" (Roberts 2000). A universal aim of urban regeneration is to deliver sustainable goals in urban development. Successful urban regeneration should correspond to different community needs. Many researchers emphasize public engagement in urban regeneration processes (Bartke and Schwarze 2015). Understanding users' preference for regeneration alternatives is important to delivering urban services that are most needed.

On the other hand, the benefits of urban regeneration can be diminished by rising land values. Cameron discusses gentrification as a potential side effect of urban regeneration. Cameron claims that although a moderate land value increase is considered a positive outcome, high property value can lead to gentrification (Cameron 2003). Gentrification is known to bring economic powers to an area and disturb its demographic makeup. In this case, the role of the local government becomes pivotal in maintaining the social landscape (Couch and Dennemann 2000). Research argues that for any change to happen, it is key to find a balance between policy change, community engagement, and technology implementation.

Principles of urban regeneration

The principles of urban regeneration focus on a variety of elements and themes of urban studies. It lays out key pillars to approach regeneration initiatives and highlights parameters of urban development. It includes relevant environmental, economic, social, and urban elements. Moreover, urban regeneration principles address the overall strategy and roles of involved stakeholders (Figure 7) These principles include (Table 1.1.1):

Table 1.1.1 Urban regeneration principles

Regeneration principle	Notes
Strategy	A comprehensive form of practice and innovation integrated with goals and policies
Environmental approach	Focus on environmental improvements in the context of prevailing sustainability issues
Economic focus	Establish a balance between public and private funding and interests
Social context	Address local needs and involve the community in guiding initiatives
Stakeholders	Create balanced partnerships between actors
Spatial boundaries	Address regional perspectives with an emphasis on the local and site levels

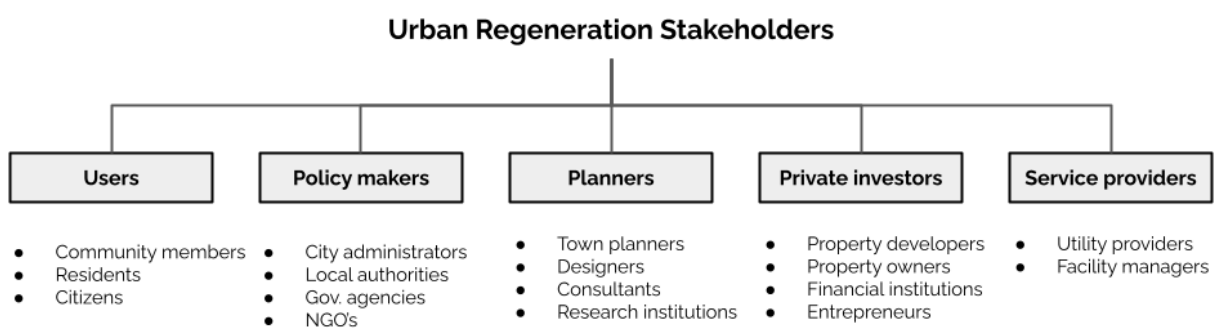

Figure 7. Stakeholders involved in urban regeneration projects

Assessing urban regeneration

Urban regeneration assessment approaches use indicator-based frameworks that include contextual measures that identify baseline parameters (Wong 2000). Some of the indicators are easier to measure than others, therefore, a combination of quantitative and qualitative data is often used. Overall, most available research put forward sustainability criteria on which the success of urban regeneration can be measured (Zheng 2014). For an accurate assessment, the sustainability criteria should establish a baseline for social and economic conditions. The complexity of the assessment can be controlled by incorporating other indicators (Coombes et al. 1992). Other studies have used scenario analysis and geographic information systems that specify the chosen criteria for the analysis (Hemphill et al. 2004).

Research highlight five elements that make up successful public spaces (El-Husseiny 2012). These include:

1. Social capital: includes social participation, shared interests, social cohesion, common experiences, and bonds.
2. Environment: includes environmental quality, safe and healthy environment, protection of human health, and protection of the environment.
3. Economy: include economic security and growth, meeting local needs locally, and creating a vibrant local economy.
4. Policy: include empowerment and governance, participation in decision making, democracy, and accountability.
5. Place-making: include sense of place, well designed public space, enhance place and space.

These five elements can be used to evaluate case studies of potential urban intervention. Although there is no quantitative approach was observed to these elements, they can be still used as a point of reference with other studies for areas of strengths and weaknesses.

Temporary urban regeneration

The study of short-term urban regeneration and temporary urbanism, in general, is lacking in the urban planning literature. It also receives little attention in real estate and economics literature. Most of the research has been done in the fields of urban sociology and geography. Peter Bishop and Lesley Williams work can be considered the most comprehensive work on temporary urbanism. Their book traces the history of temporary urban interventions, studies their economic and social effects, and provides a taxonomy of temporary urbanism types (Bishop and Williams 2012). Andres looks at the powers that shape temporary spaces. She argues that temporary urban intervention is capable of shifting the powers from decision-makers to the users of these spaces. Her work suggests that temporary spaces are capable, through users' advocacy and "opportunistic tactics", to evolve and become long-term or permanent urban features (Andres 2013). This is also an indication that temporary urban regeneration can help relax rigid regulations.

Urban regeneration in Riyadh

Throughout history, public space has been an integral part of social life in cities. The fragmentation of the urban fabric affects the quality of public participation in a city. This can be observed in the notable reduction of socialization in Riyadh. As a result, "people have been discouraged from playing an active part in public life. Public life has ceased to be public, and has become more insular, inward-looking and home-based; and individuals have been turned into passive participants."(Mandeli 2010). For a long time, the physical and social changes had created neglected spaces that became "a public burden and a continuous drain on urban life". These changes had "a direct impact on the creation of fragmented and polarized societies, with residential areas saddled with poor quality public spaces, which have spread fragmentation throughout society as a whole." (Mandeli 2010).

Urban regeneration principles support public space management that reduces dependency on central government funding. There are several factors that can be linked to the lack of urban regeneration initiatives in Riyadh. On one hand, most local authorities lack sustainable resources to manage public amenities. On the other hand, the private sector approaches urban regeneration opportunities as liabilities since service delivery in Riyadh can be characterized by minimal cost recovery that produces no direct profit. Many actions can be proposed to involve the government, the private sector, and civil society to bring about a new model for public space management. These include evaluating the ability of urban regeneration principles to provide social and sustainable environments.

1.1.5. Dry ports

Dry ports are inland ports that act as logistics centers and provide typical seaport services such as handling, storage, inspection, and customs declaration. Dry ports are connected to seaports and utilize rail systems for better connectivity and to reduce traffic, cost, and pollution. Dry ports are considered an effective solution in areas where lands near seaports are limited. Establishing dry ports can improve efficiency across the supply chain and enable competitiveness with other seaports. In today's bustling trade economy, dry ports became an integral part of intermodal transportation and cargo management. As cargo flows increase, dry ports help ease congestion at seaport terminals. Therefore, the seamless exchange between seaports and dry ports is important for guaranteeing an efficient supply chain. Dry ports benefit from the utilization of effective logistical tools to improve and maintain an efficient supply chain. Since dry ports are an extension of seaports, they need to keep certain level of handling abilities (Roso and Lumsden 2010). This requires reliable and efficient connectivity to the dry port. The utilization of rail transportation moves cargo in a fairly managed fashion. Therefore, eliminating unnecessary waiting time at the seaport. It also reduces environmental impact and lower greenhouse gas (GHG) emissions when compared to truck transportation (Cezar-Gabriel 2010).

Dry ports performance, similar to seaports, is measured by their processing time, throughput, and average storage time. However, there are several factors that influence the operation of ports. These include the capacity, services provided, information systems, and government policy (Jeevan et al. 2018). Bichou studied these factors to develop an approach to measure dry port performance (Bichou and Gray 2004). Their model covers a wide range of processes; however, it has been critiqued for not addressing environmental effects as part of the model (Bichou and Gray 2004). Measuring dry port performance should include the cost of transportation. Dry ports are dependent on rail transportation. The further a train needs to travel the more expensive the cargo becomes. In many cases, this cost becomes apparent when transporting empty containers due to trade imbalance. Empty container management is central to the operation of dry ports.

Riyadh Dry Port

Riyadh is an inland city with a population of over 7 million at an annual growth rate of 3.5%. Therefore, it’s no surprise that Riyadh is home to the largest dry port in the kingdom. The port was developed as part of an expansive infrastructure that relies on an extensive railroad system connecting coastal ports to Riyadh. This system was created in order to increase the efficiency of cargo movement to and from Riyadh (Bergqvist 2013). This system serves its purpose of minimizing trucking activities along major highways around the city. Due to the nature of economic activities in Riyadh, the port receives around 80,000 TEU (Twenty-foot Equivalent Unit) a day. However, due to space constraints and handling processes, the port generates a daily surplus of unused shipping containers. In some cases, the cost of transporting empty shipping containers to coastal ports and the increasingly shorter time of processing exacerbate the problem. These excess containers get stored, sold on the secondary market, or scrapped for their metal. This issue is not native to Riyadh, in fact, it's a global one. The accelerated patterns of global economic activities produce a substantial number of surplus shipping containers. Such surplus and high availability provide a valuable asset for reuse and motivation for this research.

In recent years, the dry port in Riyadh witnessed increasing freight transport activities due to the economic prosperity and overwhelming growth of the city. To process the increasing container traffic and manage empty containers the city is expanding its freight processing facilities and building new storage yards for empty containers. Additionally, the geographical location of the city hinders the efforts of traditional empty container repositioning (Li et al. 2004). Unlike coastal ports where routing empty containers are managed by the integration of simulations that determine the most suitable composition of routes based on optimal repositioning characteristics, Riyadh suffers from unbalanced directional flows that generate a large number of empty shipping containers (Bergqvist 2013) (Figure 8). Consequently, most empty containers get abandoned just because of the high corresponding cost of voyage routing (Jula et al. 2006).

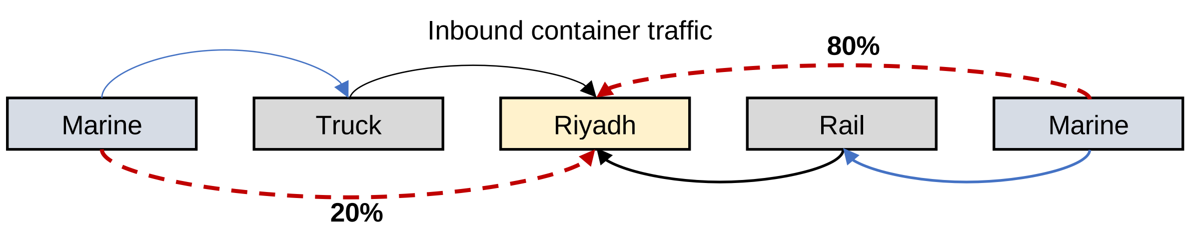

Figure 8. Inbound container traffic to the dry port of Riyadh

1.1.6. Shipping containers

Shipping containers are standardized metal boxes with a main purpose of transporting goods around the world. A typical shipping container is made from COR-ten steel that envelopes a steel frame. Both the frame and the walls are designed to manage static and dynamic loads (Slawik et al. 2010). Shipping containers can be categorized into ISO shipping containers and ISBU (Intermodal Steel Building Units) shipping containers. ISO shipping containers are exclusively used for shipping while ISBU containers can be used for building construction or storage(Levinson 2016). Shipping containers are relatively affordable units. China is the main producer of shipping containers in the world. The cost of shipping containers is mainly affected by the Chinese market. Depending on its type, the price of a new twenty-foot equivalent unit (TEU) ranges between ($2,000 - $5,000) (Abrasheva et al. 2012). The price of a used twenty-foot equivalent unit (TEU) ranges between ($1,200 - $1,600) (Abrasheva et al. 2012). There are several factors that determine the price of used containers, These include (Botes 2013):

- The type and size of the unit.
- The location of the unit (delivery cost).
- The year of production (remaining lifespan).
- The structural condition of the unit.

Construction. The COR-ten steel construction of shipping containers ensures protection from the environment and guarantees high corrosion resistance. The thickness of the corrugated steel of the walls and ceiling is 2 mm, while its depth ranges between 25, 30, and 50 mm. (Bernardo et al. 2013). The varying corrugation depth plays a role in the rigidity of the container. Likewise, the corners of the containers play a key role in their rigidity. They act as a foundation on which the container is supported and connected with other containers. Inside the container, the floor is covered by 28 mm plywood (Bernardo et al. 2013). The plywood is marine-grade made with waterproof glue and often treated with chemicals to resist rooting. Shipping containers are designed to bear heavy loads and can be stacked up to nine high when empty (Broeze 2002). When loaded, shipping containers can be stacked 6 to 8 high (ALEMDAĞ and AYDIN 2015; Ulloa et al. 2017). It is important to note that stacking requires structural calculation appropriate to each case. Further reinforcement might be necessary on a case-by-case basis (Garrido 2011).

Empty Container Management. The imbalance of cargo amounts moving globally generates a surplus of empty containers at some ports where other ports have a deficit. At the surplus ports, excess containers need to be stored as they await repositioning. The accumulation of empty containers at ports is a burden that consumes land and adds to the cost (Notteboom 2004). Empty container management is a challenging problem that must be accounted for in the cargo industry. One management tool to deal with the effects of trade imbalance is “empty container positioning”. Empty container positioning manages the flows of empty containers from surplus to deficit ports (Moon et al. 2010). This process utilizes highly sophisticated mathematical models to ensure efficiency. Even with such models, shipping companies struggle to make a profit on positioning empty containers. In 2002, empty container positioning cost shipping companies more than $15 billion USD (Song and Dong 2012). A number of studies refer to the inefficiencies in the repositioning model resulting in the accumulation of empty containers at import dominant ports (Theofanis and Boile 2009).

Shipping container architecture

Shipping containers can be an ideal tool for temporary construction. They consist of a few elements that include weathering steel, treated wood flooring, and insulation coating controlling the corrosion process. The average service life span of shipping containers as cargo units is 10 to 15 years (Grant 2013), which due to their structural standard, can be retired while structurally sound for reuse. Shipping containers are designed to sit outdoors, therefore by their innate nature, can be exposed to the natural elements.

The use of shipping containers as building units have seen an increase in popularity in recent years. Given their structural composition, shipping containers can accommodate many functions. The early recorded use of shipping containers as building units can be traced back to a 1987 patent by Philip Clark titled "Method for converting one or more steel shipping containers into a habitable building at a building site and the product thereof". The patent details the construction processes of converting shipping containers into building units (Slawik et al. 2010). Later uses of converted shipping containers into shelters appeared in the Gulf War in 1991. The first residential building that used shipping containers is Container City which was built in 2001 at London's Trinity Buoy Wharf (Figure 9) (Kotnik 2008). The containers took four days to be placed on site and another five months to finish the project. The success of this project paved the way for further experimentation in container architecture.

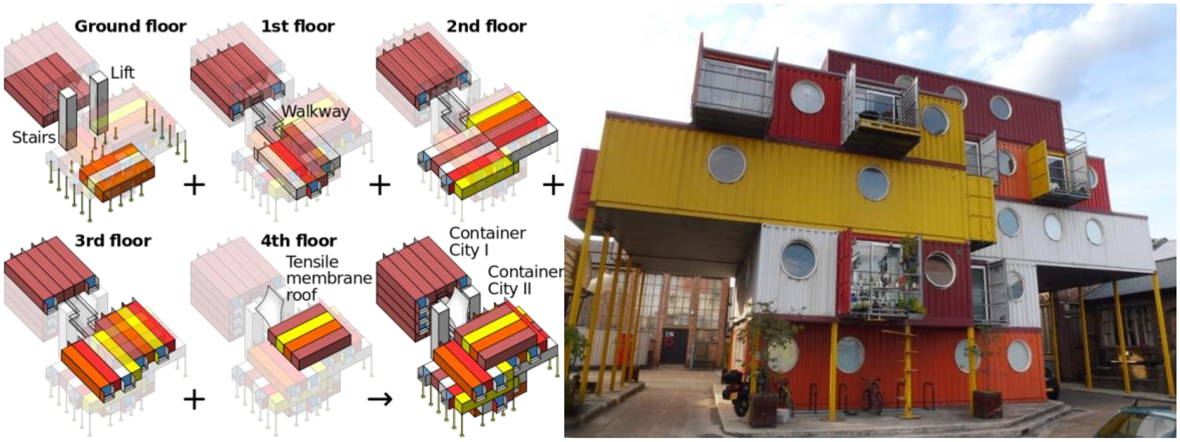

Figure 9. City Container at London’s Trinity Buoy Wharf; the first building that used shipping containers. (commons.wikimedia.org)

The use of shipping containers as building units is considered sustainable. This consideration addresses the upcycling of an otherwise downgraded resource to a higher utility product (Botes 2013). This can result in reducing embodied energy, greenhouse gas emission, and harmful waste (Vijayalaxmi 2010). Research shows a reduction of 70% in onsite waste when building with shipping containers compared with traditional construction (Islam et al. 2016). Additionally, the conversion process of shipping containers into building units consumes less energy than the scraping process (Islam et al. 2016).

On the other hand, several studies raise concerns about the amount of work and energy required for converting shipping containers to usable spaces. This process produces considerable amounts of waste material some of which could be potentially hazardous (Oshodi 2010). Other studies suggest that any intrusive alteration to container structures could significantly alter their structural rigidity (Aguiar De Souza et al. 2013). A key factor that challenges the effectiveness of shipping container structures is local building requirements (Grant 2013). These requirements help filter out containers that are not suitable for reuse.

A comparative lifecycle assessment shows that shipping container buildings have a lower environmental impact than traditional construction (Botes 2013). Compared to prefabricated construction, converting shipping containers into a building unit consumes less energy than manufacturing prefab components (Islam et al. 2016). Only during the operation phase where container construction shows the highest impact, but even then, the lifespan of the construction can play a major role. A study on the use of shipping containers as classrooms indicates that the indoor performance of these units lacks behind compared to conventional construction (Kaveh and Mahdavi 2014).

On the other hand, the conversion process of a shipping container into a habitable space is energy-intensive. It includes transportation, floor treatment, window cutting, sandblasting, and welding. All of these processes are energy-intensive, therefore they play a major role in increasing the energy consumption and environmental impact of shipping container conversion (Ismail et al. 2015). It is important to note that not all reuse attempts to shipping containers could be considered sustainable. Shipping container structure enjoys considerable advantages over traditional and prefabricated construction. From the cost, construction time, mobility, and modularity, shipping containers are a great construction alternative. However, several studies have indicated that these benefits can diminish based on the purpose and design of the unit (Islam et al. 2016).

Advantages of shipping container architecture

- **Cost.** Compared to traditional construction, shipping container construction is considered a relatively cheaper alternative. For example, in a traditional residential building, a building material can count for 55%-65% of the total cost of construction. Research shows that the use of shipping containers can cut the cost of construction by 50% (Oloto and Adebayo 2015). This shows a potential for the use of shipping containers as a low-cost alternative to traditional construction.
- **Modularity.** Shipping containers are standardized units. These standard measurements provide modular units that can shape a larger structure. Additionally, the design of shipping containers enables interlocking systems that can simplify the construction process. Additionally, the simple boxed design makes the construction flexible and easy to change the design as needed.
- **Strength.** Shipping containers are durable structures which makes them an ideal building material (Grant 2013). They are built to transport heavy cargo, stacked on top of each other, and face a harsh sea environment.
- **Time of Construction.** Shipping containers to a large extent fit the parameters of prefabricated construction. This means a shorter construction time than traditional construction. Some estimates refer to 30% less construction duration than traditional reinforced concrete buildings (Sun et al. 2017).

- **Construction Waste.** Shipping container structures can save on building materials. Typical construction processes are notorious for being resource-intensive and for producing large amounts of waste materials. In the case of shipping containers, all construction processes can see significant savings. This includes energy savings of 90%, water conservation of 40%, and waste can be cut down by 80% (Martinez-Garcia 2014).

Disadvantages of shipping container architecture

- **Thermal Performance.** The steel construction of shipping containers makes them highly conducive to heat. Containers can heat up quickly from solar radiation and cool down quickly too. This requires extensive insulation work to ensure a more comfortable interior environment.
- **Ventilation.** Shipping containers are tightly sealed to maintain a controlled environment inside. This means that in order to ventilate the space, parts of the metal should be removed and potentially replaced with other materials. The modification of the interior space often requires cutting and welding skills which are considered specialized labor.
- **Contamination.** Shipping containers should undergo a thorough cleaning process before being used as buildings. A typical shipping container is treated with solutions that contain hazardous chemicals such as chromium, copper, and arsenic. Additionally, it is difficult to determine what type of cargo was transported inside a shipping container, therefore, it is a possibility that contamination may occur inside the unit.
- **Labor.** Retrofitting shipping containers requires specialized labor capable of welding and steel cutting. Also, due to their large size, moving the containers on-site requires the use of forklifts or cranes. All of that can increase construction expenses and requires specific job site equipment. Additionally, the internal surfaces of containers should be blasted to bare metal to remove any hazardous abrasives. Any material removed should be disposed of safely.

1.2. State of the literature

Research on urban regeneration addresses a broad range of issues and covers multitudes of outcomes related to regeneration goals. Research on urban regeneration is relatively new and only gained momentum in the last decade or so (Figure 10). Early urban regeneration research focused on urban decline in order to respond to the aftermath of the 2008 economic crisis. As economic activities in cities started to slow down and vacancies started to become a feature of the urban landscape, research on urban regeneration sought to propose solutions to alleviate some of the negative impacts of the crisis. Later, research on urban regeneration broadened to cover topics of policy and governance, community and stakeholders, land use and planning, and urban design. However, within such a broad spectrum of urban regeneration topics, there are still some gaps in the literature.

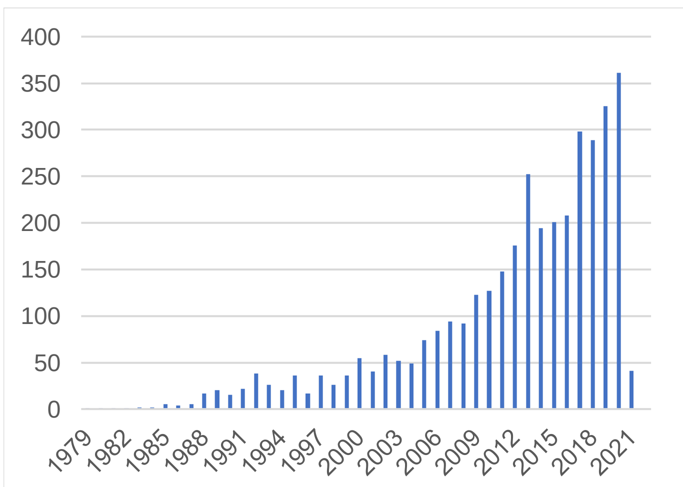

Figure 10. Trends of urban regeneration research. Publication count of articles on “urban regeneration” from Scopus database

1.2.1. Literature gaps

Addressing urban regeneration through the lens of the temporary use of vacant land is an emerging research trend. Most research on urban regeneration focuses on long-term goals and objectives. Although this research explores regeneration trends of interim use, it can highlight long-lasting effects of such temporary use. In exploring the literature on temporary urban regeneration, key themes emerged (Table 1.2.1). These themes can be grouped into four categories. First, legislative themes related to policy and governing of temporary use and occupation of vacant spaces. Research in this area addresses land-use policies, avenues of finance, and options of ownership among other themes. Second, stakeholder related theme that focuses on the roles of the parties involved. This theme addresses the responsibilities of management and opportunities for cooperation between stakeholders. Third, urban planning related theme which focuses on planning theories and planning related subjects. This theme also explores the value of regeneration achieved through temporary use. Finally, literature that focuses on design-related issues. This theme addresses design theories of temporary use, the differences and advantages of different design approaches, and their economic, environmental, and social values.

Table 1.2.1 Themes extracted from the literature on urban regeneration

	Economic	**Environmental**	**Social**
Legislative	Governance Finance Land use Use value Ownership Austerity	Policy Land use Adaptive reuse Urban transformation	Access Involvement
Stakeholders	Management Property value Value creation Food production	Urban gardens	Identity Activism Partnership Social capital Marginalized groups Community gardens Culture / art
Planning	Brownfield Urban decline Urban retail Shrinking cities Urban density Urban production Vacancy assessment Value of interim use	Climate change Use strategies Urban resilience	Public space Public amenities Emergency space Informal use Multiple-use facilities
Design	DIY urbanism Pop-up Guerrilla urbanism	Ecosystem services	Creative use Co-design Place-making Tactical urbanism

The review of research themes documented in the literature indicates a lack of knowledge in environmental research. Although the environmental effects are well documented on urban regeneration and urban vacancies research, there is a gap in the literature with regard to temporary developments. By narrowing the focus to studying the environmental impact of temporary urbanism, there is an opportunity to fill this literature gap.

Methodology Gaps

Research on temporary urban regeneration focuses on qualitative assessments of certain interventions and makes conclusions and recommendations based on the outcome of the assessments. Most studies focus on urban and infrastructure adoptions to evaluate the economic, environmental, and social capacities to accommodate such urban intervention (Kelly et al. 2015). This approach enables researchers to determine the feasibility and proof of return on the investment for the term of use and the value added to the area of intervention.

Available research falls short in quantitatively evaluating how suitable vacant lands in accommodating temporary regeneration efforts. In fact, a review of the literature revealed an overwhelming majority of research uses case studies to study temporary urban regeneration. Such a review reveals limitations of the state of the literature in providing decision support tools for urban interventions. Consequently, there is a methodological gap that can be filled to provide indicator-based assessment tools for researchers in the field.

Indicators Gaps

Research on urban regeneration highlights a gap where little research has been done. This gap pertains to indicators of sustainability assessment that help establish temporary urban regeneration parameters (Grant 2013). This includes supporting areas of research that address the triple bottom line of sustainability (Wheeler 2013). In order to create sustainable systems, the interventions in their attempt of addressing socio-environmental aspects need to be bearable, the interaction between socio-economical aspects need to be equitable, and the interplay between the economical-environmental aspects need to be viable (Figure 11). By understanding the connections between these three aspects, any proposed interventions should realize arising conflicts between these components to deliver sustainable environmental, economic, and social values. Environmental values aim to improve resource efficiency and incorporate solutions that promote healthy environments. Economic values can maximize returns by utilizing technical advances to address construction or operation issues. Social values aim to provide overall wellbeing to users while preserving the identity of the area.

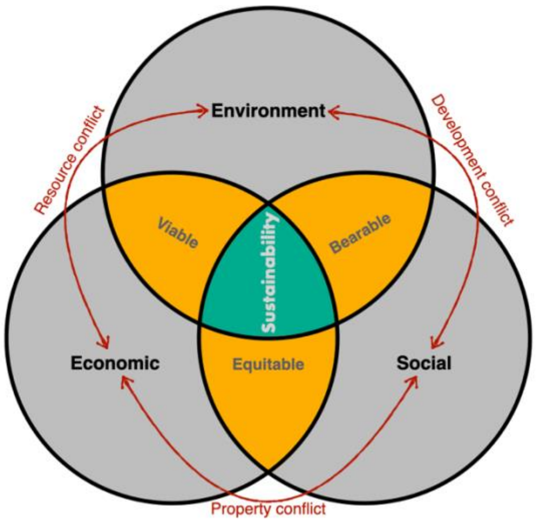

Figure 11. Triple bottom line of sustainability coupled with the “Planner’s Triangle” of fundamental planning priorities

In reviewing the literature to explore indicators based on economic, environmental, and social themes, it became clear that a large segment of available research focuses solely on urban policies. Mainly focusing on governing approaches and review of land-use mandates. These limitations can be addressed in part by studying the lifecycle of interim urban interventions based on key indicators to help develop a decision-making framework for temporary urban regeneration. This encourages opportunities for further investigation, particularly to address the following:

- The lack of knowledge addressing tools to assess temporary urban regeneration potential based on key impact indicators.
- The lack of a life cycle assessment model that integrates the key attributes of urban vacancies and temporary use to guide decision-making objectives.
- The need for a validation process to provide building blocks of evidence and relational dependencies for the life cycle assessment model.

1.2.2. Motivation

Given the parameters of the discussed issue, there is an opportunity to mitigate the prevalence of vacant lands while addressing potential uses of excess shipping containers. Through retrofitting shipping containers into usable structures, the research sees an opportunity to investigate solutions for urban regeneration that satisfy urban needs at a much lower cost and shorter time. This could be an effort to study the efficacy of upcycling valuable resources such as decommissioned shipping containers to temporary building structures. These abstract geometric forms have the potential of lowering the cost of the production of space and shorten the time of deployment. The significance of repurposing shipping containers as a building structure is mainly linked to the environmental argument of redirecting these units from being sent to waste. The flexibility of retrofitting these units for different purposes is a driving motivation for this research. Therefore, taking advantage of their mobility can expand their sustainable yield. However, reusing shipping containers as buildings could be challenging due to the physical limitations of such structures, acceptable impact levels, and the fact that they were not designed to meet building codes.

Re-thinking vacant lands as spaces that provide absent services and contain social activities is a unique approach to investigating ways of urban regeneration. This is useful in facing the increasing challenges of a rapidly changing urban environment. At the center of these challenges is new social trends resulting from demographic changes and shifts in traditional urban consumption patterns. In this light, there is an opportunity to develop a model that can help determine the need of users in the design of temporary urban space. Such a model will help determine the intended uses, the services needed, and contribute to the production of temporary space on otherwise neglected urban spaces. By identifying the needs, the research can help designers make decisions about the physical requirements that satisfy social, economic, and environmental needs. Connecting the relationship of space (vacant lands), needs (regeneration), and tools (shipping containers) may result in successful utilization of vacant lands for needed temporary urban functions (Figure 12).

Figure 12. Opportunities for temporary urban functions. Beach Canteen part of Dubai food festival (left), BIG art event in Geneva (designboom.com)

The motivation for conducting this research is to examine the use of decommissioned shipping containers as temporary spatial tools for urban regeneration on vacant lands. Several studies have examined how shipping containers can be used alternatively as structures. However, the majority of these studies focus on shipping containers as building units rather than tools for urban regeneration. The aspect of using shipping containers temporarily in an urban setting is a topic that is rarely explored. Similarly, the issue of vacant vacant lands lacks a comprehensive investigation of possible utilization during its idle stage. The motivation for this research is the opportunity for joining the two topics together. The benefit of connecting the two topics is the potential of bringing tangible and intangible value to urban settings using readily available tools. This study will help advance this research area and proposes temporary urbanism as an approach to sustainable urban regeneration.

The research sees an opportunity in studying the specified conditions of both shipping containers and vacant lands to take advantage of their common conditions for the potential of urban regeneration (Figure 13). This opportunity can be summed up in three factors. First, to study construction issues by considering the use of shipping containers as temporary units in light of urban issues. This includes studying potentials for container structures and matching it with urban objectives to fulfill any lack of services. Second, to address the local issue of excess shipping containers in cities. This includes studying systems of operation resulting in storage problems and defining solutions for reducing the number of idle shipping containers. Third, to develop a model that helps study the parameters and the impacts of the use of shipping container structures, determine their intended use, and decide upon the services it could provide. In doing so, the research will establish an empirical position of an unexplored area of research that considers common conditions between shipping containers as spatial units and White-lands as an urban environment.

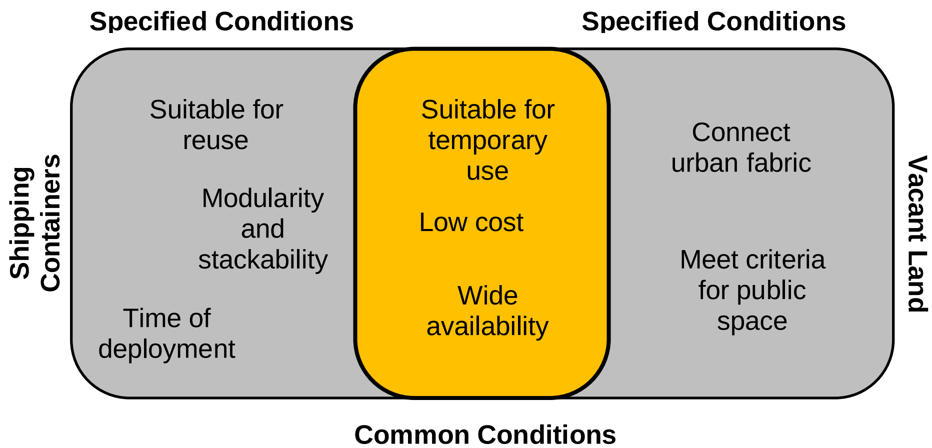

Figure 13. The motivation for the research considers studying the specified conditions of both shipping containers and vacant lands to takes advantage of their common conditions for the potential of urban regeneration

1.3. Research design

The overall goal of this research is to study temporary urban regeneration through an integrated lifecycle assessment model of vacant lands and shipping containers to determine urban regeneration potential. This includes three elements that help define the type and feasibility of temporary urban interventions. First, determine a need to be fulfilled through temporary urban function. By defining the parameters of needed urban services, the research can help determine the best use case scenarios. Second, define a function in which regeneration interventions are best suitable. Finally, guide decisions to the most feasible intervention based on lifecycle parameters.

The goal of the research will help to:

- Provide an understanding of urban regeneration principles through an empirical review of the available literature.
- Study the capability of a multi-system lifecycle approach in assessing the capacity of temporary urban interventions to help make decisions on interim use.

- Arrive at conclusions regarding the usability of shipping containers as urban regeneration tools and provide design guidelines.

1.3.1. Research Objectives

The research is motivated by two main issues. First, to address the issues of urban vacancies through temporary urban interventions. Second, to find applicable uses for idle shipping containers in an urban setting. The main benefits are to help redirect valuable resources from waste, mitigate storage problems, and measure the impact of using shipping containers as a temporary structure. This includes the following objectives:

O1: To identify the potential for temporary urban regeneration. The goal here is to study types of urban regeneration and identify potential urban regeneration solutions in the context of temporary urban development. More specifically, to understand how urban regeneration principles can be applied to combat the spread of vacant white lands in Riyadh, Saudi Arabia; and incorporate the use of repurposed shipping containers in these applications. The increasing efforts by the city to combat the high prevalence of vacant white lands encourage this research to look at urban regeneration as a tool for temporary urban development. Using shipping containers as building blocks for such developments can help fill the gap in the literature. This can be used in building the case for developing a new model with which both construction and urban issues can converge. This includes investigating the following questions:

- Q1: What existing solutions of temporary urban interventions can achieve measurable urban regeneration goals? And on what types of sites are suitable for urban regeneration?
- Q2: What principles of temporary urbanism constitute indicators of successful urban regeneration? And what are the limitations for applicable temporary urban functions?

This can be achieved by gathering data regarding urban regeneration in different contexts and finding interconnections between site types and urban functions. Through systematic literature analysis of a variety of urban principles, the research will synthesize findings that will help support urban needs that can be met using building blocks such as shipping containers. This includes the following sub-objectives:

- O1a. To identify suitable urban contexts through mapping of solutions and site types.
- O1b. To overview current best practices by studying regeneration goals.

- O1c. To document urban needs by highlighting indicators and limitations of temporary use.

O2: To propose a model for Multi-System Life Cycle Assessment (MSLCA). The goal here is to offer a model of assessment for investigating urban regeneration potential. In this light, the model provides an opportunity for research to address the convergence of separate system streams to evaluate temporary urban interventions. In this case, it includes addressing the different effects of applying literature extracted regeneration parameters to an LCA model. This covers the following supporting questions:

- Q1: What is the appropriate way to utilize life cycle assessments for a multi-system analysis involving urban interventions?
- Q2: How to make key decisions regarding connecting systems and selecting assessment parameters, indicators, and impact categories for an urban LCA?

By validating the proposed research model, the research draws connections between use cases and potential functionality. This helps determining variables for creating livable urban environments. This includes the following sub-objectives:

- O2a. To match patterns of construction and urban issues using conventional LCA steps.
- O2b. To establish a matrix of options analyzing the potential for urban regeneration.
- O2c. To help determine appropriate use cycle across multiple contexts and functions.

O3: To validate the research model. The goal here is to analyze the life cycles of both shipping containers and vacant land across shared and independent impact categories. This includes assessing scenarios of intervention suitable for short-term temporary development on vacant lands. Also, measure the impact of repurposing shipping containers into temporary structures as compared to traditional scenarios of reuse and disposal. The assessment of the potential solutions of these two seemingly separate elements is the center of this question. This includes mapping the input and output of land and container cycles to help match patterns of the overall system. This is to help build a case for the research and validate the proposed model. This includes investigating the following supporting questions:

- Q1: How does the use of shipping containers as a recycled resource impact the construction of temporary urban interventions?

- Q2: What is the impact of establishing a proposed temporary intervention on a vacant land is compared to use case pathways for both systems?

By utilizing the proposed Multi-System Life Cycle Assessment (MSLCA), the research will address key parameters of vacant lands and container structures. These include defining baseline performance of both and describing key attributes for decision making. This includes the following sub-objectives:

- O3a. To study the potential for compiling two streams of life cycle assessments to evaluate urban regeneration.
- O3b.To conduct a comparative life-cycle analysis of case studies using unconventional regeneration strategies compared to traditional use case scenarios.
- O3c. To determine the performance capacity of shipping containers as building structures on vacant lands.

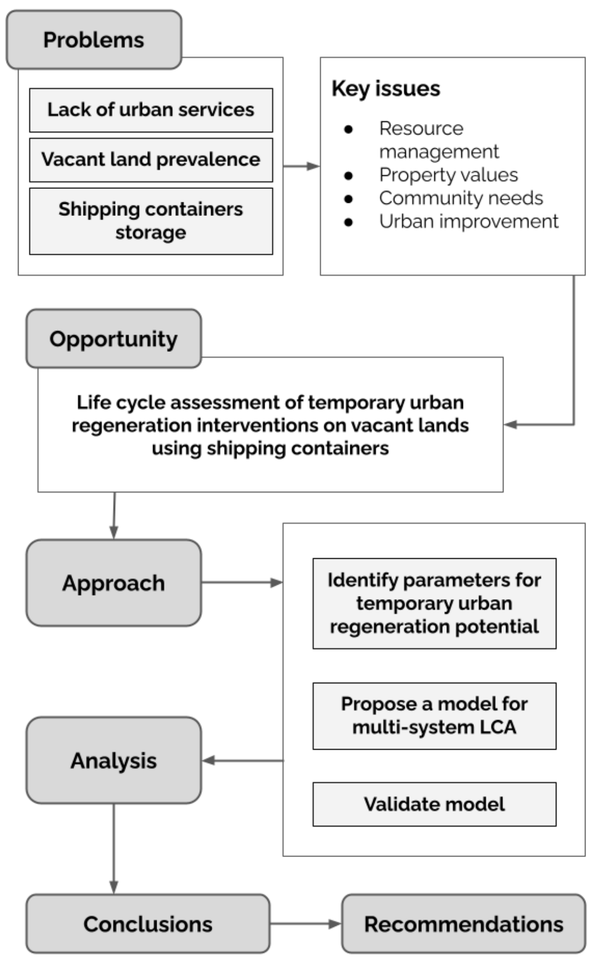

Figure 14. Overview of the research approach

1.3.2. Research Design and Approach

This part discusses the approach with which the research objectives will be addressed. This includes an overview of the research design, methods, and results for each objective. Also, this part will make connections to how the methods will fit together in answering the research questions. The goal is to indicate that the research design is suitable to the intended research objectives (Figure 14, Figure 15).

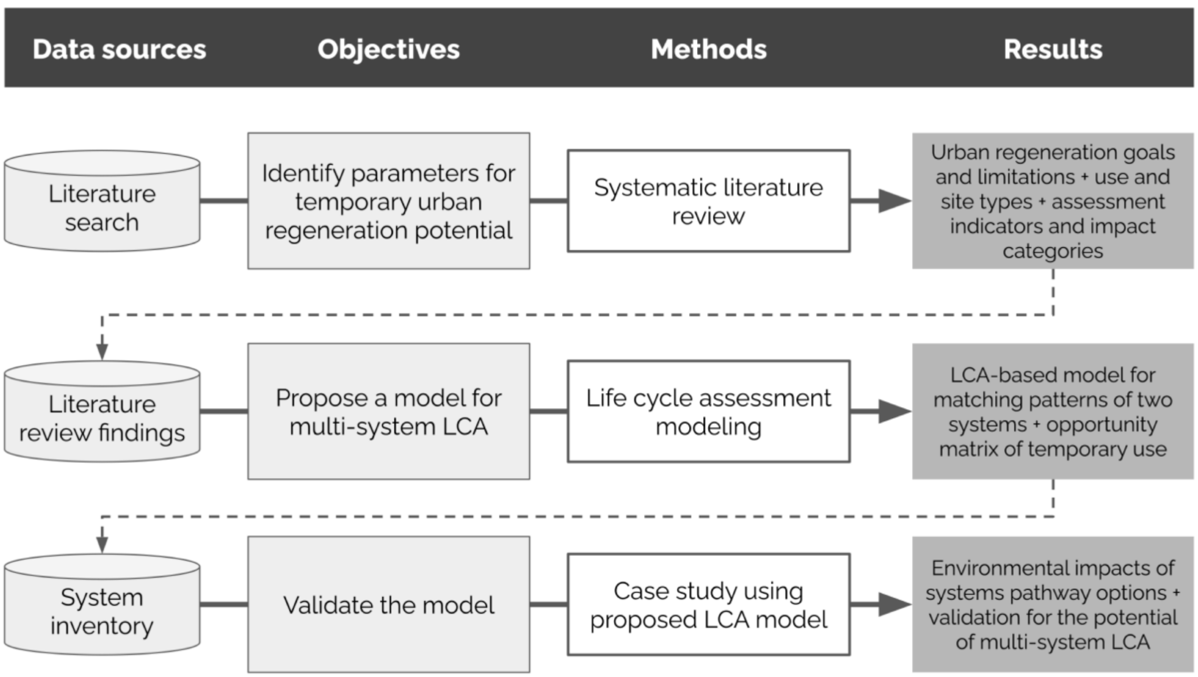

Figure 15. Overview of the research design

1.3.3. Research methods

This research takes an ambitious approach that draws from diverse disciplines. This undertaking brings together different methods in a uniquely structured methodological approach. The research uses mixed methods that include qualitative and quantitative approaches. The main methods used are systematic literature review and life-cycle analysis. The investigation of the first objective is based on a systematic literature review. This approach will be used to identify a direction for the research theory and help provide assessment parameters available in the literature. The second method that will be used is life-cycle assessment. This method will be used to analyze the convergence of the life cycles of both shipping containers and vacant lands at their idle stage using the proposed MSLCA model.

Systematic literature review

This is the main method that will be used to extract data regarding temporary urban regeneration. This will help draw connections between urban regeneration, urban vacancies, and temporary urbanism. This method will be used for the first objective to compile relevant data. Systematic literature review is an objective, transparent, and replicable methodology (Baumeister 2013). It involves a systematic search process that extracts literature relevant to the research question. Then, it characterizes and synthesizes findings and applies inclusion and exclusion criteria to the results. Therefore, the research will utilize relevant high-quality research that addresses the research question. By its nature, a systematic literature review can address a larger view of the research question because it addresses between-study differences. Therefore, it benefits from a broader view which one empirical study can convey (Baumeister and Leary 1997).

For these reasons, the research will use this method to establish the view of available empirical studies toward temporary urban regeneration potential and the results at which these studies arrived. Additionally, it can help identify gaps in the literature and explore indicators with which urban regeneration can be studied. This will also help formulate theories and account for inconsistencies. Consequently, the outcome of the review can lay the direction for the research.

Literature reviews of different types share five key stages that include planning, selection, extraction, execution, and communication (Gough et al. 2017). At the planning stage, a question should define what the literature review assesses and what are the underlying assumptions. Then a scope will establish criteria that will be used to select the literature. At the selection stage, a search strategy will define the most promising sources. Then these sources will be screened for relevant studies to dismiss irrelevant ones. At the extraction stage, studies will be coded by collecting information for mapping, quality assurance, and literature selection. Then, these codes will be mapped to describe the nature of the research field defined by the inclusion criteria. At the execution stage, the literature will be appraised to judge its relevance, utility, and quality, Then, the data will be synthesized by gathering the findings from the literature to answer the review question. At the final stage, the results will be communicated by describing how the review was done and the implications of the findings on decision making.

Life cycle assessment

Life cycle assessment (LCA) is a method used to assess impacts associated with all stages of a product or a system throughout its life. The potential for using LCA as a method is that it can help conduct a comprehensive analysis and avoid any narrow outlook with regard to the system's parameters. Life cycle assessments are data-dependent and typically used to compile an inventory of a system's input and output and evaluate potential impact to help make informed decisions. This method will be used for the second objective to assess different areas of impact. As discussed earlier, the goal of this research is to develop an LCA model that can be used to assess temporary urban regeneration using upcycled resources such as shipping containers. This model utilizes a multiagent approach to identify existing themes, system vulnerability, and areas of impact. In general, the LCA methodology is developed for environmental issues. This proposed model will expand to a wider range of impact categories including a focus on socioeconomic criteria. This can guide system improvements and convey the research goals.

Life cycle assessment follows four main stages that include goal and scope definition, inventory analysis, impact assessment, and Life-cycle interpretation (Baumann and Tillman 2004). The goal and scope definition stage will specify the product system of the lifecycle assessment. The inventory analysis stage will define the product system through the identification of flow diagrams with unit processes, collection of data for each process, and calculation. The impact assessment stage will assess the impact of a product system. Finally, the lifecycle interpretation stage will interpret the impact assessment results of the product system of the research.

Case study

This method will be used for the validation of the model by assessing specific characteristics of selected performance parameters as they pertain to the context of the study. This includes selecting a site that has the defining characteristics of vacant white lands. The case study will also help identify baseline performance of shipping containers as building units at the proposed site. Additionally, it will analyze and present data on the applicability of potential functions based on performance data. As a result, the findings will determine key attributes for identifying ideal performance outcomes for temporary urban regeneration using repurposed shipping containers on vacant lands.

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Chapter 2 – Manuscript One

Urban regeneration potential: a systematic literature review of temporary interventions on vacant lands

Target Journals:
Urban Affairs Review (https://journals.sagepub.com/home/uar)
Journal of Planning Education and Research (https://journals.sagepub.com/home/JPE)
Journal of Planning Literature (https://journals.sagepub.com/home/jpl)

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2.1. Abstract

Urban regeneration strategies bring resources to stimulate urban production. These resources leverage solutions that enable the morphology of space and structure. Such morphology is particularly nuanced in integrating temporary urbanism with urban regeneration. Investigating evidence of temporary urban regeneration potential proves that temporary interventions could introduce a catalyst for changing the effects of vacant lands. This systematic literature review investigates the extent to which research has progressed in studying temporary urban regeneration. In particular, it highlights principles of temporary urbanism on vacant lands to identify research gaps and overlaps between regeneration goals and temporary functions. This is to investigate urban conditions of temporary urbanism and provide specifications on regeneration strategies. The review extract means of temporary use evaluation across different environmental, economic, and social indicators to help build a use case model of temporary use based on literature trends. This is motivated by the goal of defining metrics for a tool that allows for assessing urban regeneration in a temporary context. Research shows less attention on temporary urban regeneration as most studies focus on permeant regeneration solutions. Additionally, the results cross-references documented temporary urban regeneration parameters to study interim use in light of vacant land. The results of the review are intended to guide decisions on how temporary urban needs can be filled using innovative systems that take advantage of the short-term nature of temporary urban regeneration.

2.2. Introduction

Temporary urban regeneration provides short-term solutions to complex and localized urban issues. Research on urban regeneration can be traced back to 1969. However, inquiries on the topic only started to gain interest in the last 20 years or so. Most notably, the popularity of urban regeneration as a research topic is associated with the Great Recession of 2008 (Hinkley and Weber 2020). As cities experienced the effects of economic decline, vacancies, and disinvestment; the need for research on regeneration started to become apparent. Urban regeneration research is not only limited to the economic aspect of the urban environment, it also addresses issues related to policy, society, and the environment.

The topic of temporary urbanism is still ambiguous. Our investigation of the databases confirmed that the concept is relatively new. The first peer-reviewed article on temporary urbanism was published in 2009. The article studied the phenomenon of street vendors as part of the temporal urban experience in the city of Jakarta (Yatmo 2009). The article evaluates the existence of temporary use in terms of belonging to the urban space between day and night. Only in 2014 is when more articles on temporary urbanism started to appear. A general overview of research shows a clear overlap in the subject areas between temporary urbanism and urban regeneration. Subjects that pertain to urban regeneration include environmental and social sciences, engineering, and business and management. On the other hand, the top subjects relating to temporary urbanism include social and environmental sciences, and business and management.

Despite the significant impact of vacant land on spatial segregation and socio-spatial disparities, the literature presents unique perspectives on dealing with vacant lands based on long term solutions (Kremer and Hamstead 2015). Most research indicates that urban regeneration projects favor the creation of permanent spaces such as “emblematic facilities”, that are valued based on their function, history, or design (Bouallag-Azoui and Berezowska-Azzag 2019). Temporary facilities, on the other hand, are not well documented in terms of their urban regeneration potential (Martin 2017). This lends an opportunity for investigating the potential of temporary urban interventions. Temporary urban interventions can offer “meanwhile” functions that can help achieve short-term social, economic, and environmental goals (Tonkiss 2013). For this reason, such as “interstitial urbanism” can take into account stakeholders’ needs to better understand the relevant issues and help translate it into appropriate policies (Patti and Polyak 2015).

Available research lacks a comprehensive literature review on temporary urban regeneration. Additionally, no clear evidence that supports the effectiveness of temporary urbanism to long term urban regeneration goals (Desimini 2015). The aim of this review is to identify temporary urbanism strategies documented in the literature. The results of this review are intended to shape an understanding of the potential association between urban regeneration, temporary urbanism, and vacant lands (Figure 16).

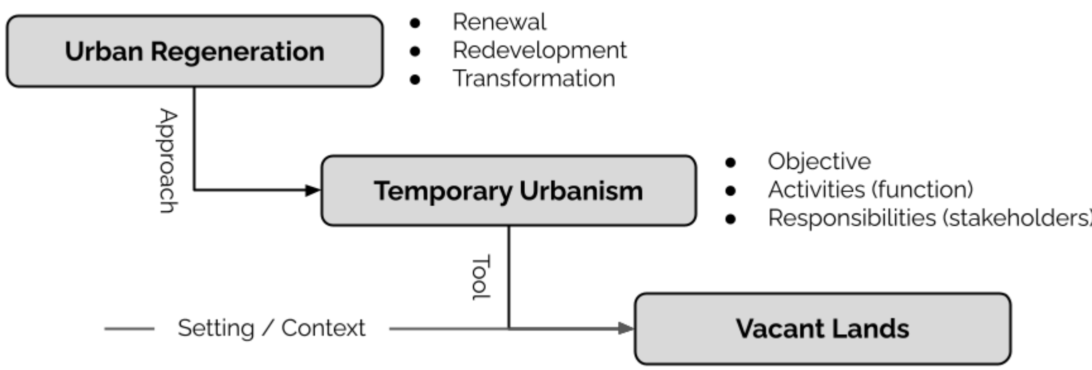

Figure 16. Key components of the review and how they connect

2.2.1. Urban regeneration

Urban regeneration research focuses on predetermined goals to achieve specific objectives. Turok (2005) argues that due to the broad range of urban needs, a common issue with urban regeneration efforts is that they are rarely comprehensive (Turok 2005). This requires a clear definition of regeneration types, objectives, and activities that address urban problems and potentials (Figure 17). Urban regeneration also involves a partnership between stakeholders to work toward common goals and objectives (Hall and Barrett 2018).

Improvements to the physical environment, social welfare, and economic conditions of an urban area are at the core of urban regeneration (Lai et al. 2018). The scope of urban regeneration covers a wide range of urban processes. These include urban redevelopment, transformation, renewal, and rehabilitation (Wang et al. 2014). Thereby the goal of urban regeneration is to "provide efficient land use and efficient use of resources, produce less waste and pollution, have comfortable traffic, ensure quality housing and livable environment, have a social, ecological and sustainable economy, preserve community participation and protect local culture” (Wheeler 2013). Roberts (2000) argues that urban regeneration efforts can help restore activities in a given territory and bring social life back. It can also enhance the sense of belongingness, therefore, it can affect local communities in more profound ways (Roberts 2000). Additionally, a sustainable urban regeneration process is capable of solving urban problems. These problems are related to quality indicators of certain sites such as the availability of open space, security, pollution, aesthetics, comfort, and cleanliness (Balsas 2000).

Existing literature shows a disconnect between urban regeneration and temporary urbanism. Addressing innovative urban interventions by exploring the role and function of temporary uses could help uncover urban regeneration goals at different scales. Understanding and analyzing how temporary uses influence environmental, socio-economic, and land use policy issues could breakdown the complexities of temporary development. Evidence highlights issues such as ownership patterns, finance, and risks of land contamination and remediation (Adams et al. 2001; Bishop and Williams 2012; Miller 2001). Most research demonstrates that optimal temporary use conditions remain unexplored in urban regeneration research. These conditions represent factors related to the site, use, and overall development process (Henneberry 2017). This represents a need for a holistic understanding of the temporary development process within a further lasting regeneration effect.

Addressing the short-term effects of temporary development as an integral part of a long-term process of urban regeneration can enable a circular approach to urban development (Bishop and Williams 2012; Madanipour 2018). Establishing interim use as a subset of a broader urban development cycle means that, as Madanipour indicates, it should be analyzed as part of the larger process of regeneration and spatial production (Madanipour 2018). This is a key factor since it involves stakeholders who define temporary use differently based on their needs and objectives. Differing implications of temporariness suggest a critical need for research to investigate temporary urbanism in order to identify its components (Henneberry 2017). Bringing together stakeholders helps make sense of varying perspectives across parameters of space and time. Coupling these two parameters presents a key contribution that highlights the role of temporary uses in stimulating urban regeneration processes. This represents a theoretical void in the literature of a circular land development process based on the value and risk of temporary urban intervention.

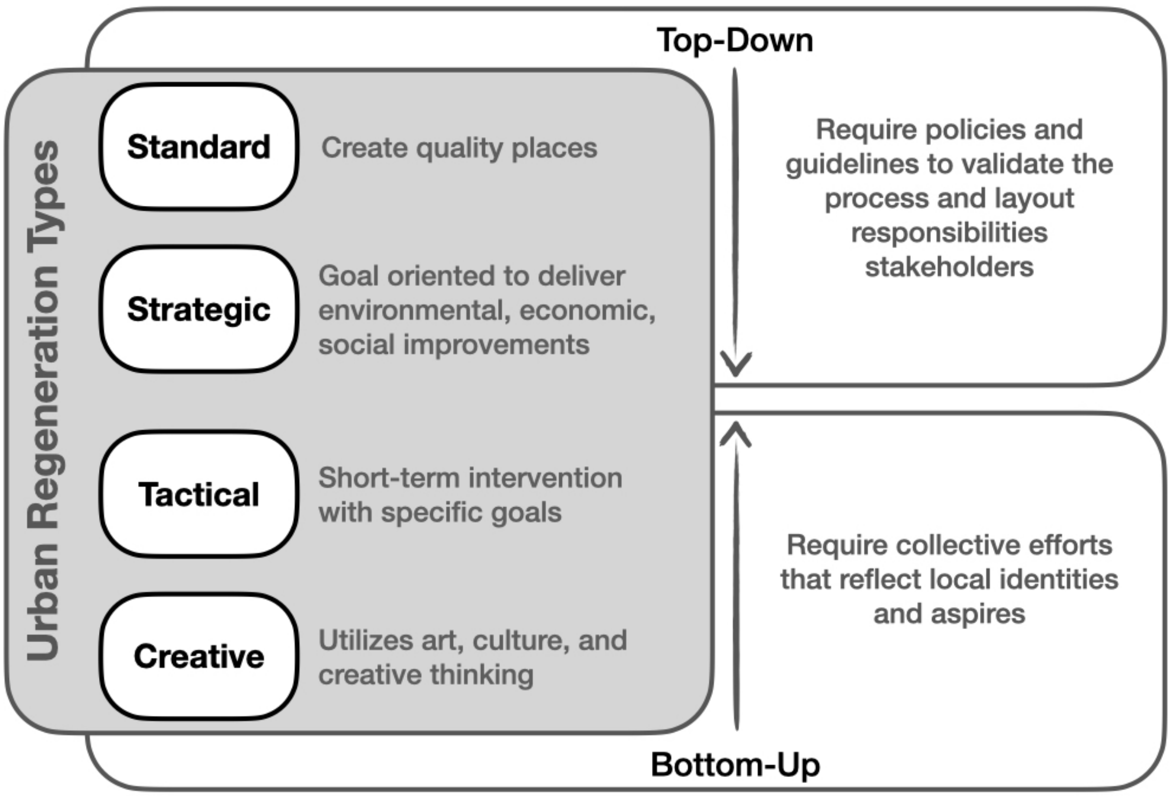

Figure 17. Overview of urban regeneration types and their distinct differences

2.2.2. Temporary urbanism

Temporary urban projects fall under the umbrella of 'temporary urbanism' which pertains to "short-term, low-cost initiatives on underutilized, vacant or public space, that aims to revitalize local life for economic or social gain". Temporary urbanism is referred to by many names, the most common terms include Tactical urbanism, DIY urbanism, Guerilla urbanism, Interim use, and meanwhile use (Bishop and Williams 2012). Temporary urbanism also includes to innovative urban interventions that could be brought about through processes of unconventional development. Temporary urbanism offers community-led, alternative solutions to pressing needs. This bottom-up placemaking approach is the defining characteristic of temporary urbanism. Most research on temporary urbanism documents the activities, space features, and contextual background of these temporary solutions.

The study of short-term urban regeneration and temporary urbanism, in general, is lacking in the urban planning literature. It also receives little attention in real estate and economics literature. Most of the research has been done in the fields of urban sociology and geography. Peter Bishop and Lesley Williams work can be considered the most comprehensive work on temporary urbanism. Their book traces the history of temporary urban interventions, studies their economic and social effects, and provides a taxonomy of temporary urbanism types (Bishop and Williams 2012). Andres (2013) looks at the powers that shape temporary spaces. Andres argues that temporary urban interventions are capable of shifting the powers from decision-makers to the users of these spaces. Her work suggests that temporary spaces are capable, through users' advocacy and "opportunistic tactics", to evolve and become long-term or permanent urban features (Andres 2013). This is an indication that temporary urban regeneration can help relax rigid regulation.

On the other hand, there are several obstacles to temporary urban regeneration. One key obstacle is the absence of a clear definition that determines what is acceptable as a temporary use for vacant land. Deslandes (2013) examines who should be involved in "DIY Urbanism" and what obstacles they may face. The research looks at the role of non-professional urban actors in reviving urban areas. Many obstacles to this type of temporary urban regeneration were observed which include social and legal factors. Other obstacles relate to land ownership that discourages any type of "meanwhile use" for the hopes of potential long-term development (Deslandes 2013).

Additionally, policy restrictions are not fully addressed in temporary urbanism research. Regulatory issues such as licensing and planning permissions are integral parts of temporary development that could determine its success or failure. Focusing on policy gaps and the complexities associated with them can challenge what constitutes a typical development cycle. Addressing critical components of the regulatory system in research can enable effective policies that could clear some of the uncertainties of temporary development.

2.2.3. Vacant land

Vacant lands are plots of lands that are not developed and show no clear plans for development. Vacant lands can either be empty lands or plots with abandoned structures. There are several factors that drive vacant sites. These mainly include market speculation and planning policy factors. Although there is little research has been done to connect market speculation to vacant land, it has been established that it's a common practice among landowners to wait for the optimal opportunity to develop vacant land (Titman 1985). Investment decisions of vacant lands can be affected by planning policy. Felipe Morandé found in a study of Santiago, Chile that factors such as the proximity to public transportation, urban density, the upkeep of the neighborhood, safety, and the shape of land are all urban factors that determine the probability for a land to be developed (Morandé Lavín et al. 2010).

Vacant lands are often considered as obstacles to urban development (Raco and Henderson 2006). Vacant lands fragment the urban environment making it less productive. Since vacant lands are part of most urban settings, they hinder necessary urban agglomeration. They also react to economic cycles and are constantly evolving to meet present needs (Moss 2003). Many inquiries cite vacancy as an opportunity for temporary development for in-between urban interventions (Johnson et al. 2009). Vacant lands are viewed as preferred sites for temporary use. However, there is a lacking inquiry with regard to spatial analysis of vacant sites suitable for temporary use. Characteristics of location, and information on the environmental conditions of the site are some of the spatial characteristics that are disjoined from interim use of vacant land research.

Most types of urban development are perceived to be beneficial to a community, however, there are several barriers to vacant land development. A number of studies suggest that land location is key in determining the success of land development. Alberto Longo studied the characteristics that enable and discourage vacant land development. The research found that lands that are located in more thriving areas are more likely to be developed than lands located in less prosperous areas (Longo and Campbell 2007). Locations that are within proximity to better urban services and appropriate infrastructure tend to develop faster in the least served areas (Lange and McNeil 2004). Other barriers to land development include low connectivity, low urban density, and lack of community support (Siebielec et al. 2012).

As interim use becomes increasingly cited as an urban regeneration approach, most literature emphasizes solutions of public engagement, adaptive policy, and finance to create solutions that correspond to different community needs (Bartke and Schwarze 2015). Vacant land development is considered to be an opportunity for user integration and community involvement. By implementing practical strategies of community engagement, land development efforts can be more tailored to users. These strategies can address issues of safety, public health, and local culture. Extending research on vacant land through the lens of temporary urbanism will benefit from a refined understanding of broader issues. Expanding inquiries to present fundamental aspects of value and time is key to evaluating risks associated with the development process (Henneberry 2017).

2.3. Methodology

A systematic literature review was used to investigate data regarding temporary urban regeneration. This helps to draw connections between temporary urbanism and urban vacancies. This methodological approach involved a systematic search process that extracts data from relevant literature. The review seeks to highlight parameters of temporary urban regeneration potential that are available in research and study indicators with which temporary urban regeneration can be assessed.

2.3.1. Review objectives

The review is formulated to examine the available evidence on how documented temporary urban interventions can achieve measurable or justified urban regeneration goals. The review is also intended to highlight principles of temporary urbanism that constitute practices suitable for successful urban regeneration. This includes exploring indications for applicable temporary urban functions.

The main objectives of the review are:

- To provide an overview of urban regeneration goals.
- To identify documented urban regeneration solutions in temporary context.
- To identify site characteristics suitable for temporary urban regeneration.
- To identify documented limitations to urban regeneration.
- To identify indicators for assessing temporary urban regeneration.

2.3.2. Search strategy

The search strategy addressed three main components, these are: search terms, databases selected, and search strings. Based on the research scope and the defined objectives, key terms were determined after conducting a pilot search (Table 2.3.1). Potential articles relating to urban regeneration, temporary urbanism, and vacant lands were identified in the pilot search of the databases. These articles were used to establish the most related alternative terms that are commonly used in the literature.

Table 2.3.1 Literature review key terms

Topics	Key terms	Alternative terms
T1: Regeneration	Urban regeneration, urban development, urban renewal, urban infill.	Spatial production, property-led regeneration.
T2: Temporariness	Temporary urbanism, Tactical urbanism, Pop-up urbanism, DIY urbanism.	Interim use, meanwhile use.
T3: Vacancy	Vacant land, unoccupied, abandoned, void.	Brownfield, grayfield.

The initial search terms were used to construct the search strings. The keywords generated for the initial search terms consulted databases for literature identification. The search terms used in the pilot search have identified a large number of irrelevant studies. For example, some terms showed results on topics outside of the review scope. Therefore, broader terms such as 'short term', 'redevelopment', and 'greenfield' were added to increase the opportunity of finding relevant studies. The initial search started with a broad scope that filtered down to more focused results while considering all source types. Then the results were narrowed into scholarly journals and peer-reviewed articles. Based on the initial search, four databases have been chosen because of the large pool of peer-reviewed articles and the high impact factor of the journals they contain on the subject of the review. The databases searched are EBSCOhost, SAGE, ScienceDirect, and Scopus.

2.3.3. Database search

The search string utilized the search terms and their alternative terms. The string is designed to link the search terms with the Boolean operator (AND) and link the alternative terms with the operator (OR). Since the review looks into urban regeneration potential of temporary urbanism on vacant lands, the search strings were built to connect these three topics as indicated in (Table 2.3.2). The search results were then documented for all search strings using a template to record the results across all selected databases.

Table 2.3.2 Search terms and strings

Search terms	Vacant; Abandoned; Brownfield; Development; DIY; Grayfield; Infill; Interim; Meanwhile; Pop-up; Property-led regeneration; Regeneration; Renewal; Spatial production; Tactical; Temporary; Unoccupied; Void
Search string	urban AND (regeneration OR development OR renewal OR infill) AND (Spatial production OR Property-led regeneration) AND urbanism AND (temporary OR tactical OR pop-up OR DIY) AND (Interim OR Meanwhile) AND land AND (vacant OR abandoned OR unoccupied OR void) AND (brownfield OR Grayfield)

2.3.4. Inclusion and exclusion criteria

The articles identified were checked to meet the inclusion and exclusion criteria. The criteria were designed to ensure that the articles were in line with the review objective. Articles that meet the inclusion criteria were referenced based on their title and abstract and categorized based on their methodological approach. The inclusion and exclusion criteria are listed in (Table 2.3.3).

Table 2.3.3 Inclusion and exclusion criteria

Criteria	
I0	Articles published in the last 10 years.
I1	Articles written in English.
I2	Journal articles only
I3	Articles that indicate from the abstract relevance to the review by addressing urban regeneration, vacancy, and temporariness
I4	Articles that indicate from the abstract providing evidence relevant to the review questions

E1	Summaries, editorials, or any research that provides insufficient information
E2	Articles that present low quality assessment score at the quality assessment stage

Articles were filtered to ensure that it follows the inclusion and exclusion criteria. The first two inclusion criteria to be applied were language and year of publication (I0, I1). This criterion was applied using automatic database filtering tools. Once articles have been identified, duplicates were removed. A reference manager application was used to achieve this task. Any remaining duplicates were removed manually. If multiple articles reported data from the same study, only the main findings were used to avoid duplication. Then, the exclusion criteria (E1) was applied and any articles that meet this criterion were removed manually. Next, only journal articles that report on temporary urban regeneration were obtained (I2). Any other publication types were excluded. Then, articles were screened to ensure sufficient data were not published elsewhere (I3, I4). Finally, the remaining articles were subjected to quality assessment procedures and articles with low-quality assessment scores were excluded (E2).

2.3.5. Quality assessment

Once articles have been identified, they were subjected to a quality assessment procedure (Table 2.3.4). Articles were organized alphabetically and given an ID based on their order in the list: (A01, A02, … A0n). The quality assessment scale consists of (Yes, To some extent, No) questions. Points were granted as follows:

- 1 point to “Yes” answers.
- 0.5 points to “To some extend” answers.
- 0 points to “No” answers.

Table 2.3.4 Quality assessment questions

Assessment question	
Question	Q1: Is the research hypothesis clear?

Theoretical approach	Q2: Is the theoretical approach of the article clear? Q3: Is there a clear statement of the research aim?
Research design	Q4: Is the research design appropriate to answer the question? Q5: Is there a clear description of the methodology?
Context	Q6: Is there a description of the context?
Data collection	Q7: Is the data collection approach described clearly?
Data analysis	Q8: Is the data analysis approach described clearly?
Relevance	Q9: Does the article discuss future work?

The goal of the quality assessment was to include articles that make valuable contributions to the review. This means including articles that showcase qualities of rigor, credibility, and relevance. Following the example of other systematic literature reviews, papers that report low and medium quality scores were excluded from the review.

2.3.6. Data extraction and synthesis

The review utilized a spreadsheet application to help streamline the review process. This tool was used to screen research, assess quality, and manage data extraction and synthesis. The data extraction process was informed by the purpose of the review and is based on research design, exposure, outcome information, and analytical methods. Custom data extraction templates were used and tailored to meet the review objectives. This means leveraging the customizable capabilities of the extraction tool. To ensure capturing available data and avoid a risk of bias, data that were not clearly provided were also documented in the data extraction forms. Any missing information was marked as “unknown” while general information was marked as “general”. Data synthesis tables were developed to meet the review questions while ensuring consistency and proper application of thematic codes. For any missing information, the articles were consulted to extract further information missing in the synthesis tables. The synthesis tables also provided a narrative description of the findings.

2.4. Analysis

The literature analysis on temporary urban regeneration commenced using the generated keywords for the selected databases. The articles were subjected to general and detailed analysis. In the general analysis themes, subject areas, and analysis approaches were extracted. This can help observe the main topics and issues, as well as, methods of analysis adopted by the literature. In the detailed analysis, the articles were assessed for quality where only relevant high-quality articles were included. Data were then extracted from the final pool of high-quality articles based on two categories of data. The first category concerns baseline characteristics that define the aims, motivation, and methodology of the literature. The second category looks into intervention characteristics that pertain to goals, indicators, and use of temporary interventions, as well as, observed limitations and proposed future work documented in the literature.

2.4.1. Literature extraction

The literature extraction process used the keywords in constructing the search strings. The application of the research strings to the four databases resulted in a total count of 606 articles divided as (EBSCOhost 56, SAGE 102, ScienceDirect 304, and Scopus 144). The references of the articles were exported to Zotero and filtered for duplication. Then, titles and abstracts were scanned to ensure their relevance and the inclusion of search terms and keywords. The resulting articles were exported, with their titles, abstracts, authors' names, and year of publication, to an Excel spreadsheet to apply the inclusion criteria. After applying the inclusion criteria, the remaining articles were shortlisted based on their access and availability. The pool of literature that remained was 101 research articles (Figure 18).

2.4.2. General analysis

The general analysis was conducted to shape an understanding of the topic of temporary urban regeneration. The analysis reveals the nuanced nature of the topic where almost 70% of research on urban regeneration was published in the last decade (Figure 19). In fact, 72% of articles on temporary urbanism were published after 2014. Even after then, the number of peer-reviewed articles is still limited across the selected databases. Moreover, the analysis reviewed trends and themes surrounding temporary urban regeneration research. This is to help set the stage for data extraction by informing necessary changes to the data extraction template.

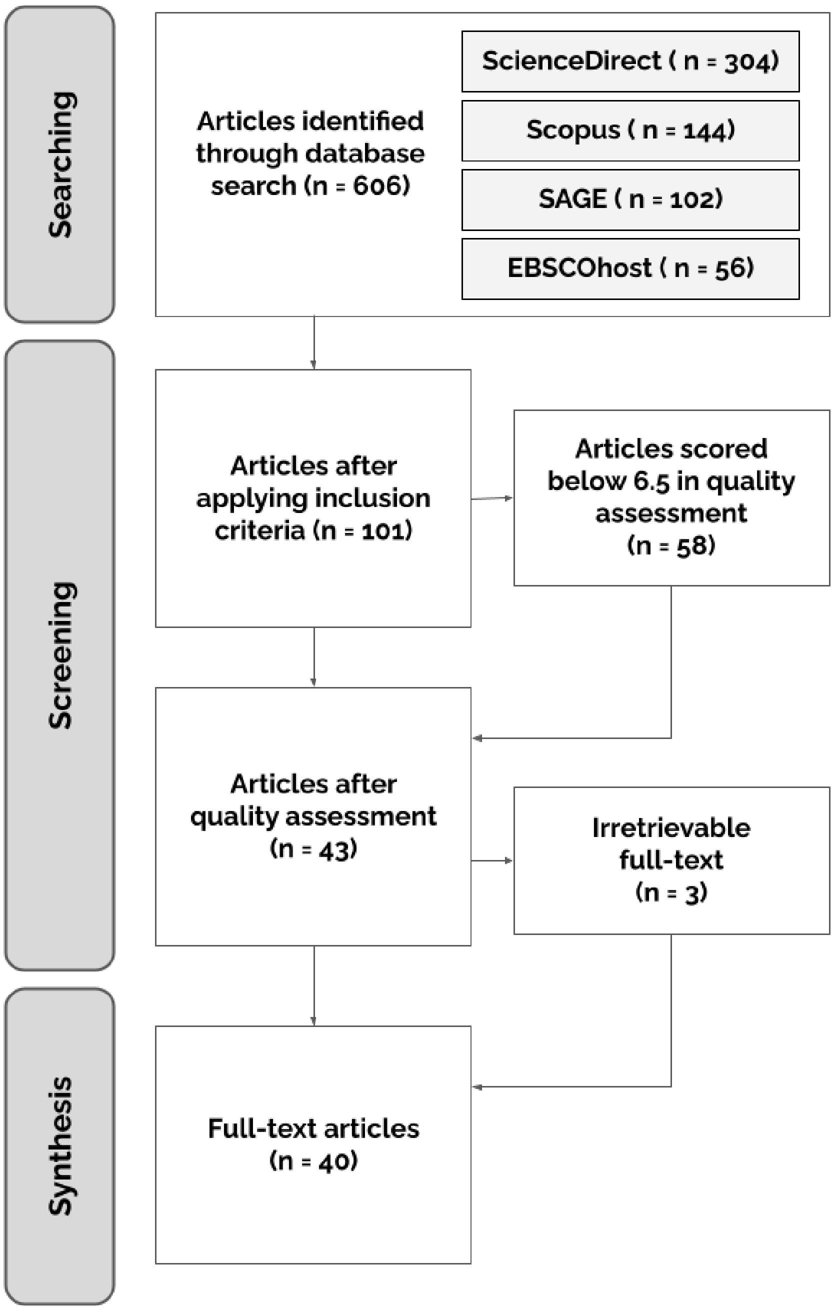

Figure 18. Flow diagram for the systematic review

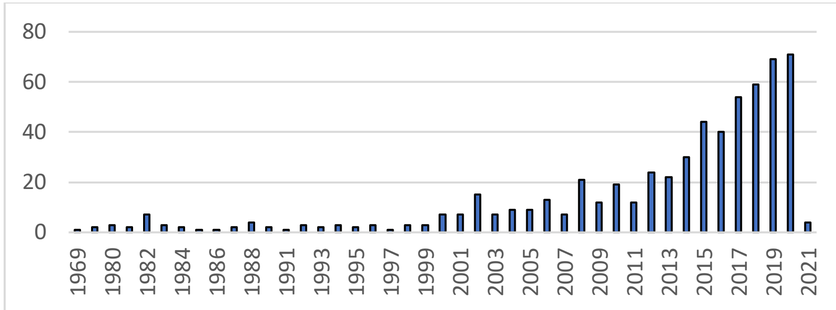

Figure 19. Historical overview of "Urban Regeneration" research

In analyzing the research methods of the reviewed literature, it has been observed that the majority of research articles adopt a qualitative analysis approach. In fact, about 60% of the reviewed articles are qualitative while 33% are quantitative and 7% are mixed-method. The distinct nature of different urban environments lends itself to site-specific research inquiries. This generally dictates methods of inquiry that most research adopts to study temporary urban regeneration cases to establish connections and draw relative conclusions. Through analyzing research methods, we found that the most common methods are: case study (47), literature review (13), interviews (8), and policy analysis (5).

In reviewing the subject areas of focus in the literature, we observed reoccurring subjects that appeared to dominate the literature. Planning policy was by far the most frequent subject. This is not surprising since most temporary urban interventions are not feasible without a planning policy that could allow them to occur (Carmon 1999). Although temporary land uses are typically considered a bottom-up approach to urban regeneration, most literature looks at planning policy as a main subject of inquiry. The second subject area that emerged from the review is regeneration strategies. Research in this area addresses theories and concepts of temporary urban regeneration. Some of these concepts have a planning theory footing that supports them, others are more concerned with studying strategies based on designs and users' involvement. The third subject area pertains to stakeholders. Those are all parties involved in aiding, facilitating, or benefiting from the project. They include decision-makers, landowners, users, and any other group of people who might be involved at any stage of the intervention cycle. The fourth subject area focuses on community-led interventions. Most of the literature on this area analyzes case studies of urban regeneration efforts piloted by the local community. The fifth subject area addresses issues of urban decline. Research in this area looks at the economic benefits achieved from temporary use in mitigating the effects of urban decline.

The analysis also looked into the connections between economic, environmental, and social subject areas in the literature. Most literature on temporary urban regeneration falls under these subjects as they are integral parts of urban sustainability research. The analysis indicates that these subjects can be independent or integrated. Moreover, policy was observed to be a secondary subject that guides a substantial portion of the literature (Figure 20).

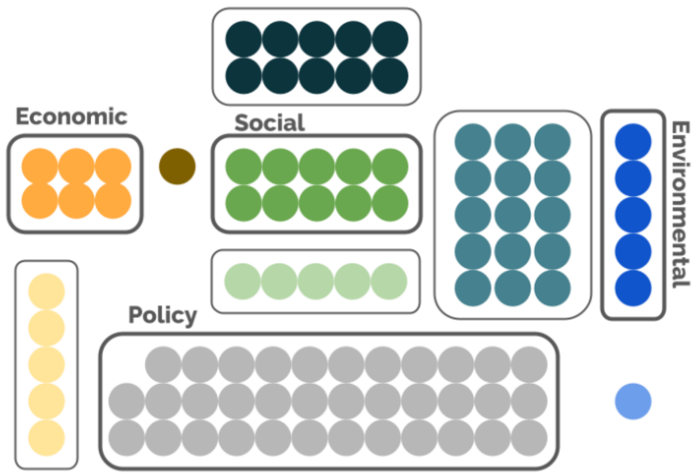

Figure 20. Literature connection across environmental, economic, social, and policy themes

Economic research indicates a focus on value creation in addition to other parameters of finance, management, and ownership. Economic indicators observed in the literature can be divided into broad indicators and site-specific indicators. Broad indicators consider the general economic environment by looking at parameters such as fiscal change, growth, and stability. Site-specific indicators represent capital and operation parameters directly related to the intervention. These include land, design, legal, construction, maintenance, lost opportunity cost, …etc. Environmental themed research highlights issues of ecosystem services, climate change, microclimate, production, and environmental protection. Some of the general environmental indicators documented in the literature include habitat value, landscape connectivity, and land protection. On the other hand, site-specific indicators include impact to the site, urban heat island effect (UHI), and greenhouse gas effect (GHG). Social themed research addresses parameters of users' needs, engagement, and participation. Some of the indicators documented in the literature include patterns of utilization and stakeholders' perceptions of temporary uses. These indicators are addressed through the lens of urban and population change, and through the characteristics of the site and its geographical location.

2.4.3. Detailed analysis

The 101 research articles were subjected to the quality assessment procedure that addresses the approach, context, and subject of inquiry. The review intends to only include the top third of highly scored articles in the review. This means setting a score threshold by which the top 34 articles are scored. Based on the results of the quality assessment, the 6.5 score represents a clear threshold (Figure 21). Among the 101 research articles, 43 articles scored 6.5 or above. The full-text of these articles was extracted from the databases and archived for the literature review. The full-text of three research articles was unavailable leaving 40 research articles available for the review.

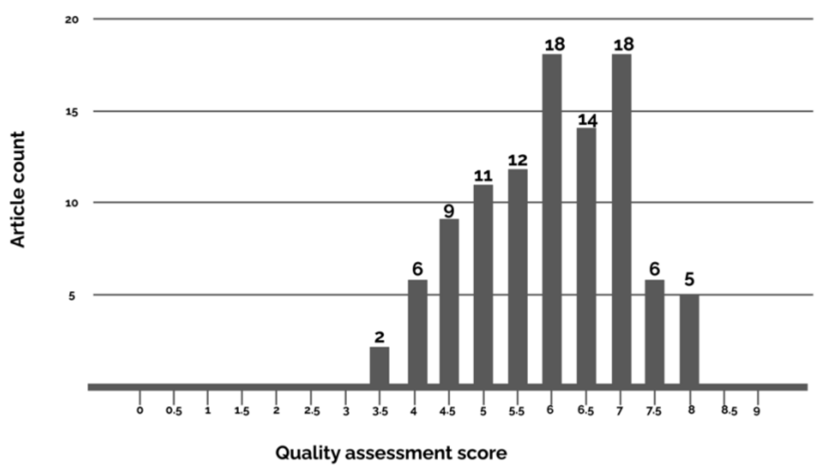

Figure 21. Articles distribution based on quality score

2.5. Results

The 40 reviewed articles addressed a broad range of temporary urban regeneration goals, limitations, and assessment indicators. The articles also presented a variety of site characteristics on which temporary uses occur and how they can affect regeneration efforts. Additionally, the articles covered use cases of temporary interventions and their influence on the environmental, economic, and social environments. However, analyzing the use cases highlighted a clear disconnect between evaluating indicators and temporary development opportunities. Most of the research was site-specific and focused on evaluating case studies. The extracted data lacked value-based outcomes that could guide measurable temporary use decisions. Alternatively, the articles provided an overview on issues of management, access, and finance of temporary urban uses on underutilized sites.

2.5.1. Use and site categories

The categories of use identify the specific use case for temporary interventions. These are use solutions that are generally dictated by the urban needs and regeneration goals. The review identified five use categories, these are; community spaces 51%, urban agriculture 24%, natural spaces 11%, commercial spaces 8%, and urban services 6%. The review also highlighted the flexibility of temporary uses in providing urban services to a wide spectrum of site types (Figure 22). The interim nature of temporary use allows it to accommodate what the site conditions permit. The review observed that temporary uses occur on four site categories. These categories refer to the physical site characteristics which include: vacant sites, vacant structures, urban spaces, and natural spaces.

The review revealed that vacant sites are the most prevalent site type utilized for temporary use as it is referenced in 64% of the reviewed articles. Vacant sites are plots of land with no or minimal manmade features which include brownfields, derelict and abandoned lands, wastelands and contaminated sites, and plots of land that are pending development. Vacant structures, on the other hand, were only referenced in 12% of the reviewed articles. These are plots of land with a physical manmade structure which include vacant buildings, ruins, and abandoned or underused structures. Urban spaces were also considered in 10% of the literature to be sites where temporary uses may occur. These are public spaces within the urban boundaries that could allow temporary uses which include parks, public spaces, parking spaces, sidewalks, …etc. In addition to urban spaces, natural spaces such as green spaces and nature preserves were also mentioned in 5% of the literature as suites suitable for temporary use. Finally, other site types that appeared in 9% of the literature include rooftops, balconies, flowerbeds, among other sites.

Research on urban vacancy presented a look into the potential unexpressed values of these spaces. Many argue that the interim development of these spaces can provide unique regeneration opportunities (Mahmoudi Farahani and Maller 2019). Vacant lands in particular offer greater development potential than other vacant site types (Newman et al. 2017). A notable advantage to vacant lands is that they provide wider flexibility and require minimal site preparation for temporary uses to be established. Research shows lasting environmental, economic, and social improvements to studied areas resulting from temporary vacant land development (Kay et al. 2019). Unsurprisingly they are consistently found to be the top most reoccurring site type across observed temporary uses.

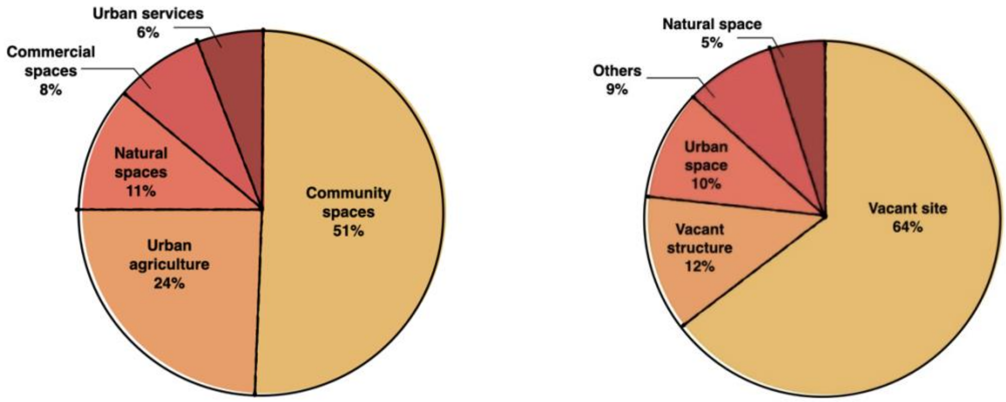

Figure 22. Temporary urban regeneration use categories (Left), and site types (Right)

2.5.2. Urban regeneration goals

Temporary use aligns itself with urban regeneration goals in bringing observable benefits to the urban environment. These goals can be considered on the basis of their environmental 34%, economic 7%, social 30%, and urban benefits 29%. Reviewing temporary urban regeneration literature based on these benefits highlighted a balanced distribution of inquiry among these benefits except for economic benefits which appear to receive less attention.

The environmental goals of temporary urban regeneration addressed a wide range of issues some were overarching environmental considerations and others were more site-specific issues. General environmental benefits included ecological benefits such as ecosystem services, increase biodiversity, provide habitats, and help in environmental cleanup (Burkholder 2012; Carlet et al. 2017; Hou and Grohmann 2018; Korsunsky 2019; Loures and Vaz 2018; Newman et al. 2017). Site specific environmental benefits included preserving greenspace by diverting development, protecting the land from contaminants, providing green infrastructure, enhancing connectivity, and providing access to nature (Bardos et al. 2016; Kamvasinou 2011; Kay et al. 2019; Madanipour 2017; Németh and Langhorst 2014; Pluta 2019). Intervention specific environmental benefits included land and resources protection, contaminants removal, and material reuse (Lokman 2017; Unt and Bell 2014; Ziehl and Oßwald 2015).

The economic goals of urban regeneration concern issues of cost, return, and the overall economic environment. Most reviewed literature claimed that temporary uses were a more cost-effective alternative to a typical urban development process. This is generally attributed to the low cost of infrastructure and management of such uses (Burkholder 2012; Németh and Langhorst 2014; Petríková and Szuhová 2017; Unt and Bell 2014). On the issues of return, research argued that temporary uses were effective in increasing the value of the site on which interventions occurred. Additionally, the financial return of temporary uses has a trickledown effect on the urban environment (Carlet et al. 2017; Draus et al. 2020; Freybote et al. 2017; Kay et al. 2019).

The social goals of urban regeneration addressed in the reviewed literature included benefits to the user, community, and urban area. Users of temporary uses benefit from having their needs met. Temporary uses can create environments for leisure and recreation which can improve users' health by providing places for physical activities. Temporary uses can also be a tool for education by fostering a learning environment (Calvet-Mir and March 2019; Hou and Grohmann 2018; Lak and Zarezadeh Kheibari 2020; Lokman 2017; Loures and Vaz 2018; Martin et al. 2019; Pluta 2019). The community for which temporary uses are provided can benefit from the opportunity to self-organize, lead change, generate social capital, and be involved in decision-making (Carlton and Vallance 2017; Kay et al. 2019; Kim et al. 2020; Mudu and Marini 2018; Ziehl and Oßwald 2015). Finally, areas where temporary uses occurred benefited from blight reduction and lower crime rates. They also attracted outside visitors and enhanced the sense of belonging in locals (Freybote et al. 2017; Gasperi et al. 2016; Newman et al. 2018).

The urban goals of temporary urban regeneration centered around issues of functionality and urban change. Some of the urban benefits of temporary uses are increased land use functionality by creating new uses on available infrastructure (Gasperi et al. 2016; Loures and Vaz 2018; Martin et al. 2019; Németh and Langhorst 2014). Other benefits consider the change brought by the temporary use which can accelerate urban change. Temporary uses are capable of changing the urban character and creating a new urban identity. This is a hallmark of temporary uses in utilizing flexible environments (Draus et al. 2020; Kamvasinou 2011; Madanipour 2018; Ziehl and Oßwald 2015). Finally, temporary uses can be tools for increasing livability through resilient processes of change (Burkholder 2012; Freybote et al. 2017; Lokman 2017).

The review revealed that community and urban agriculture spaces provided the most documented temporary regeneration benefits across all goal categories. In many urban areas, the availability of these spaces is limited for a number of reasons. Temporary community spaces offer a response to such challenge by providing informal settings on which community tailored uses can occur. Similarly, urban agriculture can provide productive spaces capable of mitigating broader environmental and health issues. A main contributor to the success of these spaces is the clear definition of community engagement process. One that is capable of fulfilling specific needs.

Research points out that for such a process to work, municipalities need to provide policy-driven incentives to encourage the involvement of community groups. Both community and urban agriculture spaces fit the participatory approach of temporary urban regeneration. They are generally managed by either non-profits, citizen groups, or individual community members. Bolstering this operational goal encourages the local community to participate and take action. Regardless of how small or incremental these actions are, they allow users to be the agents of urban change they aspire to see in their community. Successful temporary appropriation of vacant lands can help uncover the real value of derelict vacant lands.

2.5.3. Urban regeneration indicators

The goal of urban regeneration indicators is to assess the effects of temporary urban interventions. These indicators could be general performance metrics or specific intervention related indicators. Indicators of urban regeneration observed in the reviewed literature can be divided into environmental, economic, social, and urban indicators (Figure 23). Environmental indicators addressed issues of climate change, ecological impact, and emissions. They also considered site-specific indicators such as soil, water, and waste. Additionally, they factored contextual environmental hazards such as hurricane risk and flood plains (Bardos et al. 2016; Lak and Zarezadeh Kheibari 2020; Li et al. 2019; Newman et al. 2017; Pluta 2019). Economic indicators addressed issues of funding, cost, and revenue as well as the economic environment overall. Some of the indicators included property value, household income, economic growth, and direct and indirect costs and benefits (Freybote et al. 2017; Li et al. 2019; Mudu and Marini 2018; Németh and Langhorst 2014; Newman et al. 2018; Pothukuchi 2018). Social indicators addressed issues of use, utility, and value. Some of the documented social indicators included equity, engagement, impact, perception, and social value (Burkholder 2012; Kamvasinou 2011; Kay et al. 2019; Kim et al. 2020; Li et al. 2019; Winter et al. 2020).

Finally, urban indicators relate in parts to the intervention's characteristics such as type of use, function, and duration. Other urban indicators included parameters of ownership, stakeholder, and city role (Freybote et al. 2017; Hugo and du Plessis 2020; Kirnbauer and Baetz 2012; Lak and Zarezadeh Kheibari 2020; Mahmoudi Farahani and Maller 2019; Martin et al. 2020; Unt and Bell 2014; Wesener 2018). Throughout the review process, it has been observed that assessment indicators were applied, by a significant margin, to interventions taking place on vacant lands.

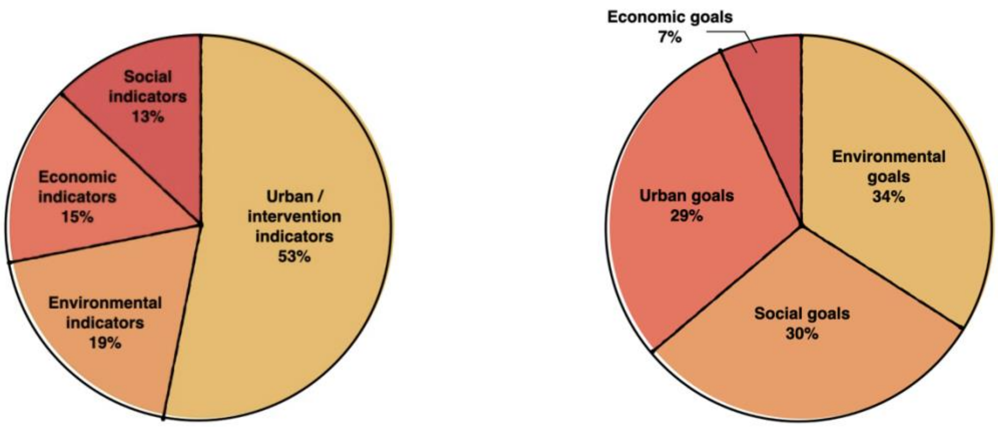

Figure 23. Distribution of urban regeneration indicators (left) and goals (right) of reviewed literature

2.5.4. Limitation to temporary uses

Urban regeneration research highlighted key limitations to temporary uses. These limitations were grouped into five categories, these include: environmental, economic, social, contextual, and policy related limitations. Environmental limitations addressed issues of contamination and environmental gentrification (Carlet et al. 2017; Freybote et al. 2017). Economic limitations addressed issues of revenue, real estate value, and economic feasibility (Burkholder 2012; Ziehl and Oßwald 2015). Social limitations considered issues of inclusivity and equity of access and participation. It also addressed the local acceptance and perception of temporary uses and investigates opportunities for user engagement (Demailly and Darly 2017; Freybote et al. 2017; Lak and Zarezadeh Kheibari 2020; Lokman 2017; Mikadze 2020; Mudu and Marini 2018; Pothukuchi 2018; Unt and Bell 2014). Contextual limitations addressed case specific parameters that could affect temporary uses. Some of the observed limitations included the type of use, duration, scale, design, ownership, and stakeholders' demand (Draus et al. 2020; Ferreri 2020; Martin et al. 2019; Tonkiss 2013; Winter et al. 2020). Finally, policy related limitations documented in the literature included issues of urban policy, building codes, zoning and land use change.

The documented limitations to urban regeneration revealed the case specific nature of temporary interventions. The most reoccurring limitation categories across observed use cases were contextual limitations. These limitations showcased the dynamism of temporary regeneration and that documented temporary uses were dependent on a broad range of circumstantial elements. Additionally, social and policy issues presented a substantial set of limitations to urban regeneration. A significant portion of the literature highlighted related issues that hindered temporary uses either directly or indirectly.

2.5.5. Connecting the results

In analyzing the results, the review connected physical intervention parameters of temporary use that included the site and use types to goals, limitations, and indicators of urban regeneration. A radial network diagram was created to provide a comprehensive overview of the interrelationships between these elements (Figure 24). The goal of the diagram is to draw connections between the aforementioned elements and to display current areas of interest and potential avenues for future research.

As observed by the review, community spaces and urban gardens built on vacant lands represented the most documented site and use types. The review showed the effects of these uses and land types on the literature. For example, the two use types provided over 81% of the documented limitations to temporary urban regeneration. Similarly, vacant lands provided 72% of the indicators and 50% of the goals documented in the literature. In reviewing the relationship between site and use types to regeneration goals, the review revealed a strong focus on social, urban, and environmental goals. This is in line with the common notion that temporary uses are either public initiatives or community-led, therefore, they are primarily established to serve social and urban goals.

Less research is conducted on economic goals. Several articles highlighted economic goals of temporary use. Most notably, research on economic benefits of urban farming showed that it did not bring lasting economic returns when compared to commercial or community uses. Most documented social goals addressed benefits to the community while urban goals address policy related issues. Finally, environmental goals addressed provisioning services and connecting landscapes.

With regard to the limitations of temporary uses, social and contextual limitations were the most dominant in the literature. The urban context of the intervention played a key role in limiting regeneration efforts. The land size is one limiting factor to temporary use. Left-over space and odd-shaped lands although may seem suitable for temporary functions, most research labels them as potential obstacles to permanent development. Finally, reviewing indicators to assess temporary use revealed a spread across all four categories, however, Urban indicators were at a slight advantage.

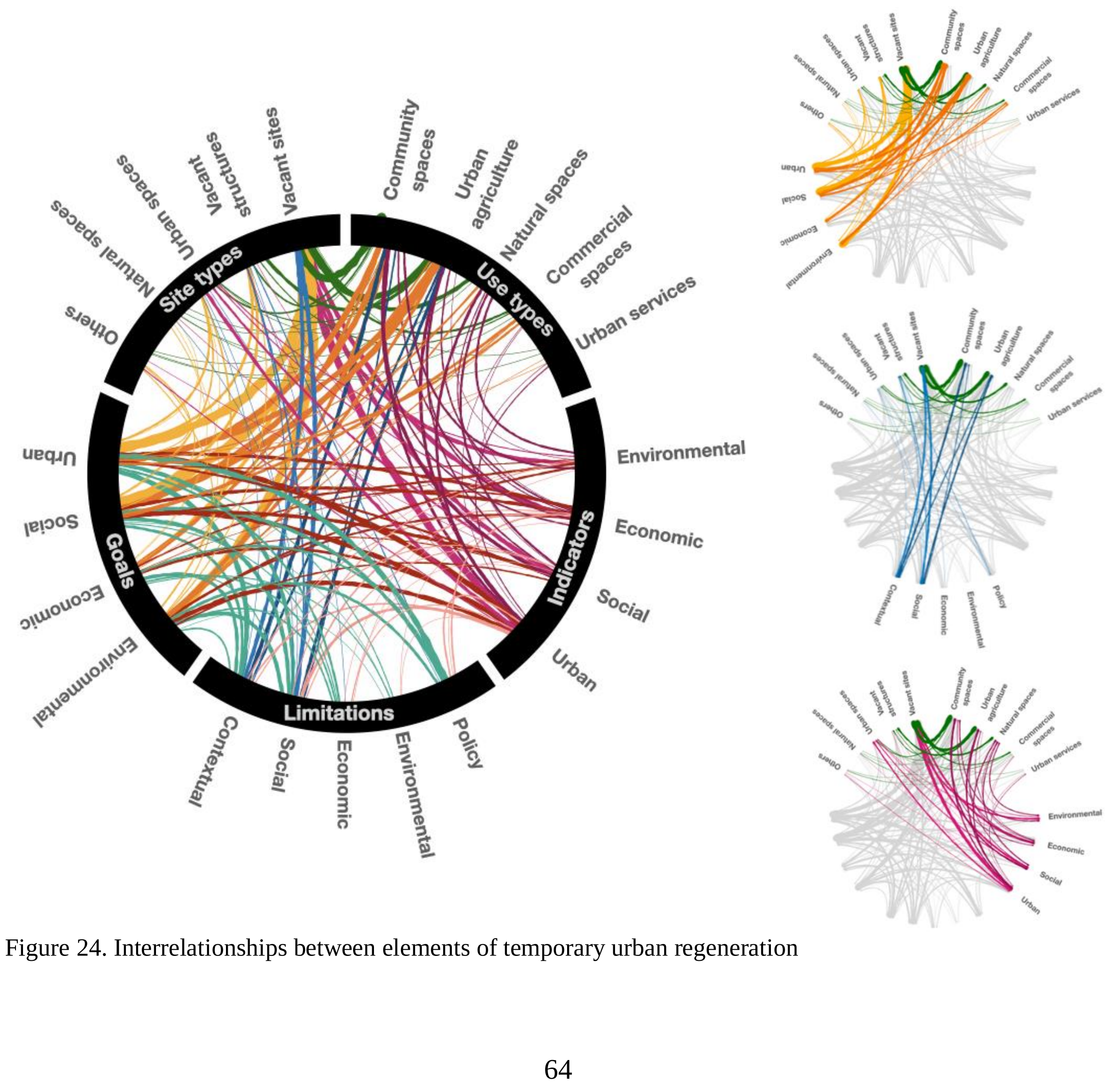

Figure 24. Interrelationships between elements of temporary urban regeneration

2.6. Discussion

The challenge of vacancy that many urban areas face is that they require unique approaches to provide context-sensitive opportunities for different programs and interventions. Reviewed studies pointed out that most successful temporary urban regeneration programs follow unique approaches characterized by community engagement, environmental responsibility, and flexible policy. These programs pave the way for experimenting with regeneration strategies that envision new social and environmental relationships. These strategies are also great tools for creating appropriate policy approaches, funding frameworks, and participation models that accommodate different uses and site categories. The strategies can be summarized into the following takeaways (Figure 25):

- It should be based on informed and detailed analysis of the urban context.
- It need to address the environmental conditions, economic base, social structure, and urban fabric.
- It requires a developed strategy that conform to regeneration goals and objectives.
- It aligns the strategy with policies and regeneration initiatives.
- It makes responsible use of environmental, economic, social, and urban resources.
- It establishes effective cooperation between stakeholders.

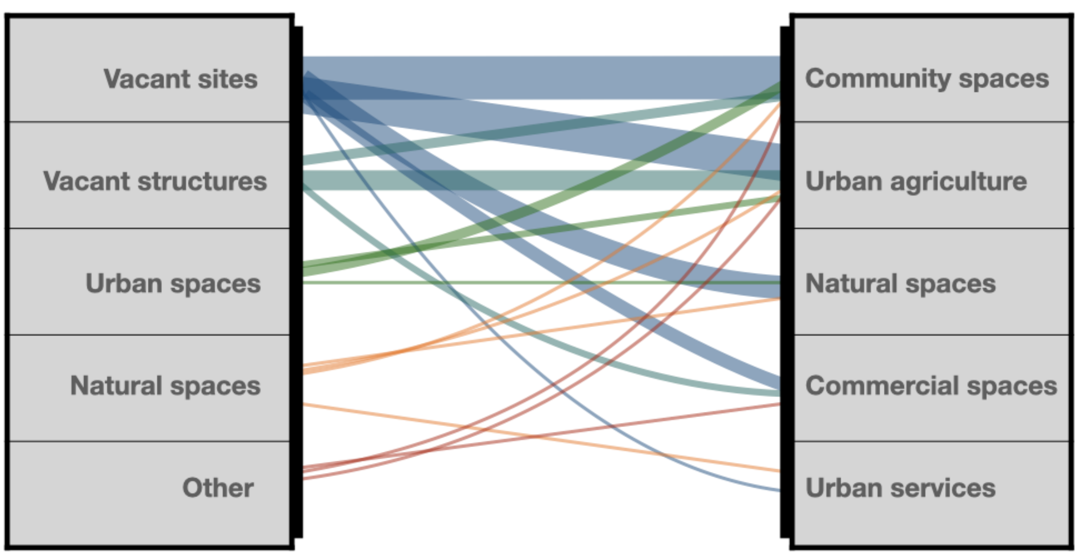

Figure 25. Cross-relationships between site and use types of temporary urban regeneration

2.6.1. Understanding temporary urban regeneration

Temporary developments deal with a different set of stakeholders. It brings actors interested in investing their time, physical abilities, and social capital. Such unconventional actors challenge the conventionally regulated and increasingly privatized public development projects. They introduce a significant shift in goals from other stakeholders; such as developers' business goals, landowners' long-term development goals, and policy makers' burden-shifting goals. Consequently, temporary developments could be a source of contention between stakeholders. In a competitive development market, private developers rarely commit to short-term developments as they may pose a threat to their own development aspirations. This is particularly true in high-profile temporary developments, the very ones that could raise awareness about the benefits of temporary use and educate the public about regeneration programs. Similarly, landowners are observed to show low interest in temporary uses due to the low returns. They often prefer market powers to bring permanent development regardless of how distant in the future such opportunity is.

To encourage all stakeholders to engage in temporary vacant land development, goals and objectives should be shared around creating unique and genuine urban spaces that bring mutual benefits to all. Lower overheads, infrastructural upgrading, environmental protection, and the creation of public space are some of the benefits of temporary urban regeneration. Finally, a cross-sector partnership is bolstered by flexible policy, and the availability of practical information, technical knowledge, and financial means to all stakeholders.

2.6.2. Assessing temporary urban use

Temporary use strategies should approach temporary uses as stopgap, short-term interventions with long-term effects especially when responding to the prevalence of vacant lands. Most reviewed strategies approached temporary uses as a means rather than an end for urban regeneration. This raises a fundamental concern by policymakers regarding the associated costs weighed against the benefits of such uses. Such concerns can be mainly addressed by demonstrating the value of temporary uses. A key value proposition to temporary uses is it low-cost, short-term, and that it does not impede future development. In fact, they can be tools for attracting newcomers and developers, therefore, increasing property values in the area. Additionally, temporary uses are often used as means for revitalization and rebranding urban areas making them attractive for further development. Such potential, if supported, can encourage the allocation of further public resources for temporary uses. This requires further research on value-related indicators. This includes use value, opportunity value, and rates of monetary value change brought by temporary developments.

Showcasing value-related benefits to temporary use can help bring stakeholders abroad. Generally, value determinations of temporary uses are considered on the basis of actual commercial value, however, research shows the potential of use value as a more holistic measurement of value. Use value address broader indicators such as environmental effect, social engagement, as well as economic potential. Use value can help portray the long-term benefits of temporary use. Approaching temporary use based on use value allows for evaluation concepts that consider indicators of interest to a larger group of beneficiaries not just politically or financially stronger stakeholders. This approach helps rally stakeholders around shared goals with a communal strategic commitment that brings closer competing interests. It could also be a balancing tool, as each regenerating case is unique, a clear role definition is important to share roles and express values between stakeholders and relieve pressure off municipalities and policymakers.

2.6.3. Urban policies

The concept of urban regeneration assumes a comprehensive set of tools to tackle specific problems. Urban policy plays a significant role in establishing regeneration strategies. Such policies need to be built on common goals and supported by active participation and partnerships. Research highlights the lack of interest by municipalities in temporary use due to a lack of evidence on their efficacy and uncertainties about their actual cost. Increasingly public institutions have shifted the responsibility of temporary spaces to community organizations or the private sector. This creates spaces that either lack regulatory oversight or are heavily commercialized. By its nature, temporary uses can create innovative experiences that could benefit from public control or private economic interest. However, these experiences need to incorporate social and economic measures to address the benefits of such physical transformations to users. Temporary uses are seen as effective ways to unlock the potential of underutilized spaces. They are also recognized as democratic tools for space production. Therefore, research recognizes the degree of stakeholders' involvement in delivering intended goals and avoiding to only benefiting some. A strategic urban regeneration policy should ensure an inclusive approach that fairly benefits all the different actors involved.

2.7. Conclusion

The review set out to explore research on temporary urban regeneration. Given the potential for temporary uses to redevelop underutilized urban spaces, the review investigates knowledge regarding the temporary use of vacant lands. The review classifies urban conditions observed in research to provide specifications for temporary use and taxonomy of urban regeneration goals and strategies. This revealed how hard is it to define urban regeneration and how the concept evolved over time. Since the concept of urban regeneration is broad, the review attempts to draw connections between physical urban parameters and use related parameters in order to understand the potential of urban regeneration based on environmental, economic, and social values.

Temporary urban regeneration is not a linear process. In many observed cases, it is a creative and collaborative process that arises from non-traditional boundaries. They create appropriate environments that serve a particular purpose and provide great opportunities for experimental learning. Results from the review show temporary interventions as transformative tools that can add environmental, economic, and social values. Considerable focus in the research is given to vacant land as non-productive spaces that could provide sites to test regeneration hypotheses. Vacant lands are valuable assets that could be detrimental to an urban area. Their prevalence can affect property values, economic opportunities, and neighborhoods' urban and social fabrics. The review breaks down spatial and temporal complexities of temporary urban regeneration to provide a guide for future research.

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2.9. Appendix

Table 2.9.1 Top research subject areas observed in the literature

Subject areas	Count	References
Planning policy	47	(Andres and Golubchikov 2016; Benjamin 2020; Bertino et al. 2019; Calvet-Mir and March 2019; Carlet et al. 2017; Certomà 2016; Colomb 2012; Demailly and Darly 2017; Desimini 2015; Dombroski et al. 2019; Dubeaux and Cunningham Sabot 2018; Fagnoni et al. 2017; Galdini 2020; Gasperi et al. 2016; Grimaldi et al. 2019; Gulin Zrnić and Rubić 2018; Harris 2015; He 2019; Herbert 2018; Honeck 2018; Hou and Grohmann 2018; Hudson 2015; Kim et al. 2020; Lak and Zarezadeh Kheibari 2020; Lau 2012; Lee and Newman 2017; Li et al. 2018; Liu 2017; Mahmoudi Farahani and Maller 2019; Martin et al. 2019; Matoga 2019a; b; Mudu and Marini 2018; Nefs et al. 2013; Newman et al. 2016b; a; O′Callaghan et al. 2018; O′Callaghan and Lawton 2015; Patti and Polyak 2015; Pothukuchi 2018; Reynolds 2011; Schaller and Guinand 2018; Scott and Szili 2018; Shaw 2014; Thorpe 2018; Tonkiss 2013; Zebracki 2018)
Regeneration strategies	26	(Andres and Golubchikov 2016; Bertino et al. 2019; Berwyn 2012; Bragaglia and Caruso 2020; Cardullo et al. 2018; Certomà 2016; Desimini 2015; Dubeaux and Cunningham Sabot 2018; Fagnoni et al. 2017; Galdini 2020; Grimaldi et al. 2019; Harris 2015; He 2019; Hudson 2015; Hugo and du Plessis 2020; Imam 2014; Jaspers and Steen 2020; Ladzianska 2012; Lak and Zarezadeh Kheibari 2020; Lau 2012; Martin et al. 2019; Matoga 2019b; Németh and Langhorst 2014; O′Callaghan and Lawton 2015; Olivastri 2017; Reynolds 2011)
Stakeholders	21	(Andres 2013; Bertino et al. 2019; Cardullo et al. 2018; Desimini 2015; Dhingra et al. 2016; Dombroski et al. 2019; Fagnoni et al. 2017; Glover 2019; Harris 2015; Herbert 2018; Kamvasinou 2017; Kim et al. 2020; Kirnbauer and Baetz 2014a; b; Lak and Zarezadeh Kheibari 2020; Liu 2017; Martin et al. 2019; Matoga 2019a; Moore-Cherry and Mccarthy 2016; Patti and Polyak 2015; Vallance et al. 2017; Zebracki 2018)
Community-led development	17	(Andres 2013; Cardullo et al. 2018; Certomà 2016; Fagnoni et al. 2017; Ferreri 2020; Galdini 2020; Herbert 2018; Herman et al. 2018; Kim et al. 2020; Kirnbauer and Baetz 2014a; b; Olivastri 2017; Patti and Polyak 2015; Shaw 2014; Thorpe 2018; Wesener 2015; White and Bunn 2017; Zebracki 2018)
Economic decline	16	(Andres 2013; Berwyn 2012; Calvet-Mir and March 2019; Dubeaux and Cunningham Sabot 2018; Grimaldi et al. 2019; Harris 2015; Herbert 2018; Kamvasinou 2017; Ladzianska 2012; Lee and Newman 2017; Martin et al. 2020; Németh and Langhorst 2014; O′Callaghan et al. 2018; O′Callaghan and Lawton 2015; Reynolds 2011; Tonkiss 2013)
Spatial characteristics	11	(Campo 2020; Dhingra et al. 2016; He 2019; van der Hoeven and Hitters 2020; Honeck 2018; Hudson 2015; Li et al. 2018; Lokman 2017; Martin et al. 2020; Pluta 2019; Unt et al. 2014)
Types of vacancy	10	(Campo 2020; Honeck 2018; Hugo and du Plessis 2020; Lee et al. 2018; Li et al. 2018; Loures and Vaz 2018; Newman et al. 2016b, 2018; Olivastri 2017; Unt et al. 2014)
Urban decline	9	(Burkholder 2012; Carlet et al. 2017; Ferreri 2020; Imam 2014; Lee et al. 2018; Lee and Newman 2017; Madanipour 2017; Nefs et al. 2013; Newman et al. 2016b)
Temporary use benefits	8	(Cheshmehzangi 2016; Dombroski et al. 2019; Fagnoni et al. 2017; Loures and Vaz 2018; Madanipour 2018; Till and McArdle 2015; Wesener 2015; Winter et al. 2020)

Degree of impact	8	(Carlton and Vallance 2017; Cheshmehzangi 2016; Glover 2019; Loures and Vaz 2018; Madanipour 2018; Moore-Cherry and Mccarthy 2016; Pluta 2019; Till and McArdle 2015)
Intervention characteristics	8	(Freybote et al. 2017; Lee et al. 2018; Lokman 2017; Madanipour 2017; Martin et al. 2020; Németh and Langhorst 2014; Newman et al. 2016a; Unt and Bell 2014)
Value	8	(Andres 2013; Bardos et al. 2016; Freybote et al. 2017; Galdini 2020; van der Hoeven and Hitters 2020; Kamvasinou 2011; Till and McArdle 2015; Tonkiss 2013)
Decision-making	7	(Dhingra et al. 2016; Jaspers and Steen 2020; Kirnbauer and Baetz 2014a, 2012, 2014b; Li et al. 2019; Till and McArdle 2015)
Urban agriculture	7	(Carlet et al. 2017; Certomà 2016; Demailly and Darly 2017; Gasperi et al. 2016; Kirnbauer and Baetz 2012; Mudu and Marini 2018; Pothukuchi 2018; White and Bunn 2017)
Use	7	(Bardos et al. 2016; Bragaglia and Caruso 2020; He 2019; van der Hoeven and Hitters 2020; Hudson 2015; Kamvasinou 2011; Tonkiss 2013)

Table 2.9.2 Types of community spaces with literature documented use cases

Space type	Use case	Reference
Open space	Park, pop-up park, linear park, parklet	(Burkholder 2012; Draus et al. 2020; Ferreri 2020; Kamvasinou 2011; Kim et al. 2020; Lak and Zarezadeh Kheibari 2020; Li et al. 2019; Lokman 2017; Madanipour 2017; Martin et al. 2019; Winter et al. 2020)
Social space	Mixed-use community space, cultural district, sports facilities, community garden	(Carlton and Vallance 2017; Kim et al. 2020; Li et al. 2019; Lokman 2017; Tonkiss 2013)
Entertainment / Event space	Event space, entertainment complex, exhibition space, art space, artists studio, music venue, social-ecological experience, garden festival	(Carlton and Vallance 2017; Ferreri 2020; Kay et al. 2019; Li et al. 2019; Lokman 2017; Madanipour 2017, 2018; Martin et al. 2019)
Work space	Work space, DIY workshop	(Lokman 2017; Madanipour 2018; Winter et al. 2020; Ziehl and Oßwald 2015)

Table 2.9.3 Vacant site characteristics quantified based on the use category

Use category	Site characteristic	Count	Reference
Urban agriculture	Vacant land	9	(Calvet-Mir and March 2019; Carlet et al. 2017; Crowe and Foley 2017; Demailly and Darly 2017; Kim et al. 2020; Korsunsky 2019; Lak and Zarezadeh Kheibari 2020; Martin et al. 2019; Pothukuchi 2018) (Petríková and Szuhová 2017)
	Brownfield	1	(Mudu and Marini 2018)

	Abandoned land	1	
Community spaces	Vacant land	9	(Burkholder 2012; Carlton and Vallance 2017; Draus et al. 2020; Kay et al. 2019; Kim et al. 2020; Lak and Zarezadeh Kheibari 2020; Martin et al. 2019; Winter et al. 2020)
	Brownfield	3	(Li et al. 2019; Madanipour 2017; Ziehl and Oßwald 2015)
	Contaminated land	1	(Lokman 2017)
	Pending development	1	(Kamvasinou 2011)
Commercial spaces	Vacant land	2	(Carlton and Vallance 2017; Martin et al. 2019)
	Brownfield	1	(Ziehl and Oßwald 2015)
	Contaminated land	1	(Lokman 2017)
Natural spaces	Vacant land	6	(Burkholder 2012; Carlton and Vallance 2017; Kamvasinou 2011; Kim et al. 2020; Mahmoudi Farahani and Maller 2019; Newman et al. 2017)
	Brownfield	1	(Li et al. 2019)
Urban services	Vacant land	1	(Kim et al. 2020)

Table 2.9.4 Urban regeneration goal quantified based on the use category

Goal	Benefit	Use category	Count	Reference
Environmental	Ecosystem services Cool air Reduce waste Sequester carbon Impervious surfaces Storm water	Urban agriculture	6	(Carlet et al. 2017; Hou and Grohmann 2018; Korsunsky 2019; Mikadze 2020; Mudu and Marini 2018; Pothukuchi 2018)
	Site cleanup Access to nature Preserve greenspace	Community spaces	6	(Burkholder 2012; Kamvasinou 2011; Kay et al. 2019; Lokman 2017; Madanipour 2017; Ziehl and Oßwald 2015)
	Recycle material Remove contaminants	Commercial spaces	2	(Lokman 2017; Ziehl and Oßwald 2015)
	Landscape connectivity Flood protection	Natural spaces	3	(Burkholder 2012; Kamvasinou 2011; Newman et al. 2017)
	Repurpose land	Urban spaces	1	(Mikadze 2020)

Economic	Economic decline Property value Cost-effective	Urban agriculture	3	(Carlet et al. 2017; Petríková and Szuhová 2017; Tonkiss 2013)
	Financial return Property value Infrastructure cost	Community spaces	5	(Burkholder 2012; Draus et al. 2020; Kay et al. 2019; Tonkiss 2013; Winter et al. 2020)
	Revenue Value increase	Commercial spaces	1	(Ziehl and Oßwald 2015)
	Management cost	Natural spaces	1	(Burkholder 2012)
Social	User needs Social interaction Education Social integration Health Access to nature	Urban agriculture	11	(Calvet-Mir and March 2019; Demailly and Darly 2017; Gasperi et al. 2016; Kim et al. 2020; Korsunsky 2019; Lak and Zarezadeh Kheibari 2020; Martin et al. 2019; Mudu and Marini 2018; Petríková and Szuhová 2017; Pothukuchi 2018)
	Share resources Social capital Education Public engagement Self-expression	Community spaces	10	(Carlton and Vallance 2017; Draus et al. 2020; Kamvasinou 2011; Kay et al. 2019; Kim et al. 2020; Lak and Zarezadeh Kheibari 2020; Lokman 2017; Madanipour 2018; Martin et al. 2019; Ziehl and Oßwald 2015)
	User need Attract visitors Education Public engagement	Commercial spaces	5	(Carlton and Vallance 2017; Freybote et al. 2017; Lokman 2017; Martin et al. 2019; Ziehl and Oßwald 2015)
	Public space Recreation	Natural spaces	3	(Carlton and Vallance 2017; Kamvasinou 2011; Kim et al. 2020)
	Public engagement Political action	Urban spaces	1	(Kim et al. 2020)

Urban	Partnership Food provision Greenspace Reduce blight Land use functionality	Urban agriculture	10	(Calvet-Mir and March 2019; Carlet et al. 2017; Demailly and Darly 2017; Gasperi et al. 2016; Hou and Grohmann 2018; Korsunsky 2019; Martin et al. 2019; Mudu and Marini 2018; Petríková and Szuhová 2017; Pothukuchi 2018)
	Flexibility Public space Build community Urban character	Community spaces	10	(Burkholder 2012; Draus et al. 2020; Ferreri 2020; Kamvasinou 2011; Kay et al. 2019; Lokman 2017; Madanipour 2018; Martin et al. 2019; Winter et al. 2020; Ziehl and Oßwald 2015)
	Increase livability Proximity Facilitate development	Commercial spaces	4	(Freybote et al. 2017; Lokman 2017; Martin et al. 2019; Ziehl and Oßwald 2015)
	Beautification Urban identity	Natural spaces	2	(Burkholder 2012; Kamvasinou 2011)
	Sense of place Define space	Urban spaces	1	(Wesener 2018)

Table 2.9.5 Vacant site characteristics quantified based on category of regeneration goal

Goal	Site characteristic	Count	Reference
Environmental	Vacant land	10	(Burkholder 2012; Carlet et al. 2017; Hugo and du Plessis 2020; Kay et al. 2019; Korsunsky 2019; Lokman 2017; Németh and Langhorst 2014; Newman et al. 2017; Pluta 2019; Pothukuchi 2018)
	Brownfield	3	(Bardos et al. 2016; Madanipour 2017; Ziehl and Oßwald 2015)
	Contaminated land	1	(Loures and Vaz 2018)
	Abandoned land	1	(Mudu and Marini 2018)
	Waste land	1	(Unt and Bell 2014)
	Pending development	1	(Kamvasinou 2011)
Economic	Vacant land	6	(Burkholder 2012; Carlet et al. 2017; Draus et al. 2020; Kay et al. 2019; Németh and Langhorst 2014; Winter et al. 2020)
	Brownfield	1	

	Waste land	1	(Petríková and Szuhová 2017) (Unt and Bell 2014)
Social	Vacant land	12	(Calvet-Mir and March 2019; Carlton and Vallance 2017; Demailly and Darly 2017; Draus et al. 2020; Kay et al. 2019; Kim et al. 2020; Korsunsky 2019; Lak and Zarezadeh Kheibari 2020; Lokman 2017; Martin et al. 2019; Pluta 2019; Pothukuchi 2018)
	Brownfield	3	(Bardos et al. 2016; Petríková and Szuhová 2017; Ziehl and Oßwald 2015)
	Contaminated land	1	(Loures and Vaz 2018)
	Abandoned land	1	(Mudu and Marini 2018)
	Pending development	1	(Kamvasinou 2011)
Urban	Vacant land	12	(Burkholder 2012; Calvet-Mir and March 2019; Carlet et al. 2017; Demailly and Darly 2017; Draus et al. 2020; Kay et al. 2019; Korsunsky 2019; Lokman 2017; Martin et al. 2019; Németh and Langhorst 2014; Pothukuchi 2018; Winter et al. 2020)
	Brownfield	2	(Petríková and Szuhová 2017; Ziehl and Oßwald 2015)
	Contaminated land	1	(Loures and Vaz 2018)
	Abandoned land	1	(Mudu and Marini 2018)
	Pending development	1	(Kamvasinou 2011)

Table 2.9.6 Urban regeneration indicators quantified based on site characteristics

Indicator type	Indicator	Site characteristic	Count	Reference
Environmental indicators	Ecological impact Emissions Land use	Vacant land	5	(Burkholder 2012; Lak and Zarezadeh Kheibari 2020; Li et al. 2019; Newman et al. 2017; Pluta 2019)
	Land contamination	Brownfield	1	(Bardos et al. 2016)
	Ecological value	Pending	1	(Kamvasinou 2011)
Economic indicators	Sales tax Property value Economic climate	Vacant land	6	(Lak and Zarezadeh Kheibari 2020; Newman et al. 2017; Pluta 2019; Pothukuchi 2018)
	Costs and benefits Employment	Brownfield	1	(Pluta 2019)

	Funding sources	Abandoned	1	(Mudu and Marini 2018)
Social indicators	Perception Social impact Engagement	Vacant land	5	(Burkholder 2012; Kim et al. 2020; Lak and Zarezadeh Kheibari 2020; Pluta 2019; Winter et al. 2020)
	Social involvement	Brownfield	2	(Bardos et al. 2016; Li et al. 2019)
	Social value	Pending	1	(Kamvasinou 2011)
Intervention indicators	Project type Pattern of use Governance Proximity Supporting services	Vacant land	10	(Burkholder 2012; Hugo and du Plessis 2020; Kim et al. 2020; Lak and Zarezadeh Kheibari 2020; Mahmoudi Farahani and Maller 2019; Martin et al. 2020; Németh and Langhorst 2014; Newman et al. 2017; Pothukuchi 2018; Winter et al. 2020)
	Use potential	Abandoned	1	(Mudu and Marini 2018)
	Use value	Pending	1	(Kamvasinou 2011)
	Activity type	Wasteland	1	(Unt and Bell 2014)

Table 2.9.7 Urban regeneration limitations quantified based on use category

Use category	Limitation	Count	Reference
Urban agriculture	Urban policy: (policy, gentrification)	7	(Carlet et al. 2017; Hou and Grohmann 2018; Korsunsky 2019; Martin et al. 2019; Mudu and Marini 2018; Petríková and Szuhová 2017; Pothukuchi 2018)
	Social: (Access, equal participation opportunity, local participation)	6	(Carlet et al. 2017; Korsunsky 2019; Martin et al. 2019; Mikadze 2020; Mudu and Marini 2018; Pothukuchi 2018)
	Contextual: (Duration, scale, use, landowners, land acqisition, site limitations, land ownership)	4	(Carlet et al. 2017; Demailly and Darly 2017; Martin et al. 2019; Tonkiss 2013)
	Environmental: (Soil contamination, environmental gentrification)	1	(Carlet et al. 2017)

	Economic: (long-term feasibility)	1	(Carlet et al. 2017)
Community spaces	Urban policy: (Policy, land use change, municipal burden, building code)	3	(Ferreri 2020; Martin et al. 2019; Winter et al. 2020)
	Social: (Inclusivity, inequality of access, equal participation opportunity, access, perception of vacancy)	4	(Burkholder 2012; Lak and Zarezadeh Kheibari 2020; Madanipour 2018; Ziehl and Oßwald 2015)
	Contextual: (Property owners, stakeholders' demands, duration, scale, use, landowners, cost, lost of space, construction material, connecting to urban context)	7	(Burkholder 2012; Draus et al. 2020; Ferreri 2020; Martin et al. 2019; Tonkiss 2013; Winter et al. 2020; Ziehl and Oßwald 2015)
	Economic: (revenue)	2	(Burkholder 2012; Ziehl and Oßwald 2015)
Commercial spaces	Urban policy: (policy)	1	(Martin et al. 2019)
	Social: (inclusivity)	1	(Ziehl and Oßwald 2015)
	Contextual: (Property owners, stakeholders' demands, landowners, parking availability)	3	(Freybote et al. 2017; Martin et al. 2019; Ziehl and Oßwald 2015)
	Environmental: (trash accumulation)	1	(Freybote et al. 2017)
	Economic: (Revenue, increase real estate value)	2	(Freybote et al. 2017; Ziehl and Oßwald 2015)

Chapter 3 – Manuscript Two

Life cycle assessment model for temporary urban regeneration: a multi-system approach using vacant lands and shipping containers

Target Journals:
Environment and Urbanization ASIA (https://journals.sagepub.com/home/EUA)
Planning Theory (https://journals.sagepub.com/home/PLT)
International Journal of Urban and Regional Research (https://onlinelibrary.wiley.com/journal/14682427)

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3.1. Abstract

Temporary uses can provide urban regeneration opportunities by allowing site-specific interventions on underutilized sites. For these tailored short-term interventions to achieve sustainable objectives; they need to benefit from using low-impact tools in their design and construction. Repurposing vacant sites and upcycling material are two widely adopted practices for temporary urban regeneration. However, available research lacks comprehensive assessments that could guide decisions on environmental and socio-economic impacts of such interventions. This research proposes a methodological framework to assess the life cycles of vacant lands and decommissioned shipping containers to help determine their capacities to serve temporarily as urban regeneration tools. The overarching goal of the model is to connect two life cycles and assess their joint effects in creating a system that addresses an observed problem. The resulting Multi-System Life Cycle Assessment (MSLCA) model contributes a systematic process to evaluate the components necessary to create environments that serve successful regeneration objectives. The model proposes procedures to highlight elements of the problem, identify pathways for solutions, and examine outcomes. This is achieved by building on literature findings to create system boundaries, determine assessment indicators, and plan intervention scenarios.

Keywords: Life cycle assessment; Shipping containers; Temporary urbanism; Urban regeneration; Vacant land.

3.2. Introduction

Life cycle assessment (LCA) is a method used to assess impacts associated with all stages of a product or a system throughout different stages. Life cycle assessments typically compile inventories of a system's inputs and outputs to evaluate their potential impacts to guide informed decisions. The impact of a product depends on decisions taken throughout its life cycle. This includes processes at the end-of-life (EOL) stage. Adding additional processes beyond this stage can render a product as a resource for a new use. Assessing the life cycle of a product after the "end-of-first-life" stage can highlight the value of reuse. Extending the life of a product, through reuse or repurposing, can bring a range of benefits. These benefits are mainly related to energy, material, and carbon savings (Adler et al. 2007). Most products require an upfront energy investment for material extraction, manufacturing, and transportation among other processes. Furthering the return on the embodied energy by finding a second use can potentially extend the value of a product during its use stage. The impact of reusing a product depends on its nature and the processes of its life cycle. Some products require significantly more energy during the material extraction or manufacturing phases than during the use phase (Ashby 2012). These types of products are best suitable for reuse due to their lower use impacts (Figure 26).

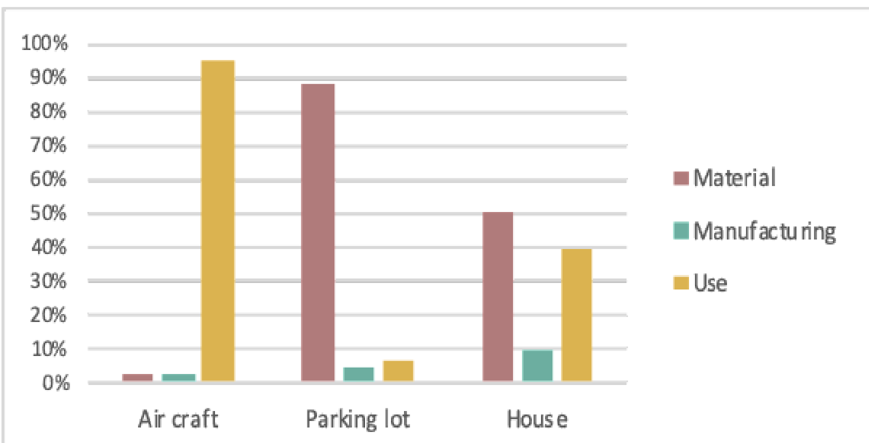

Figure 26. Life cycle energy consumption of different products

In the case of shipping containers, the embodied energy is relatively low for the use stage. Most of the energy is needed for the material extraction and manufacturing stages. This is the case with most "unpowered" products as they benefit from higher use stage efficiencies. The literature indicates that reusing such products increases the sustainable return on their embodied energy

(Cooper and Gutowski 2017). Similarly, repurposing idle shipping containers for a different use may require energy for reuse, but could still be lower to cases of new product use.

3.2.1. Temporary urban regeneration

Temporary urbanism research focuses on creative solutions while falling short in investigating the development process of temporary solutions (Henneberry 2017). Analyzing the process of property development in light of interim use is useful in identifying key indicators. A dominant focus in research highlights factors that include economic, cultural, and regulatory factors. These factors are influenced by the prevailing local perception of temporariness that dictates the variables and risks associated with the development process (Bishop and Williams 2012). A critical exploration of these factors identifies a relationship between physical environmental needs and behavioral and societal needs (Moore-Cherry and Mccarthy 2016). Most literature neglect to comprehensively highlight that the fulfillment of these needs differs from one site to another. This explains why the production of temporary urban environments does not follow a typical development process and therefore constitutes its own efforts of inquiry.

The nature of temporary development poses a number of challenges that pertain to future land development. A number of studies highlight the risk of temporary uses taking opportunities away from permanent development (Blumner 2006; Reynolds 2011). A successful temporary solution can become an asset that could be a subject of community resistance when it reaches the end of its development cycle, and consequently, deter future development of the site. When users become attached to a meanwhile site, conflicts of interest may arise (Blumner 2006). This has the potential to discourage landowners from allowing interim uses on their sites. Another risk of temporary use is the potential of its blocking permanent development (Bishop and Williams 2012). Even though research on temporary use hasn't indicated it in discouraging permanent development, it still appears to be affecting interim use (Henneberry 2017). Many landowners may prefer to keep their land vacant than to allow temporary use (Reynolds 2011). This ambiguous nature of temporary development makes it difficult to accept interim use as part of the cycle of land development.

Additionally, the cycle of development received little attention in the literature. On the issue of time, research makes generic claims and refers to site-specific factors such as context and scale (Tonkiss 2013). This shows the limitation of temporary urbanism research and highlights a need to explore the role of temporary use in achieving regeneration objectives. One way to address this issue is by studying the connections between temporary use and land vacancies. This can be achieved through a model that integrates key factors of the development cycle into an analytical framework to create a decision-making device that takes context, duration, and scale into account. Such an approach can address the complexities associated with temporary development and the challenges of vacant lands. Understanding the role of temporary development in this light helps justify the rationale of establishing interim uses within a circular development process.

3.2.2. Shipping container structures

Repurposing decommissioned shipping containers as structures for temporary use reduces the demand for materials needed for building new structures. In fact, shipping containers are manufactured to a high structural and material standard which makes them ideal tools for construction. Such properties, in addition to their standard dimensions, put shipping containers at an advantage as short-term modular structures since they use fewer materials and have lower embodied energy compared to conventional construction. Given their structural characteristics, shipping containers are rigid, lightweight, and fire and rust resistant (Grant 2013). They can also be highly efficient due to their tight seal and material. For temporary uses, they can be comparable if not a superior option. In fact, shipping container structures can consist of up to 75% of recycled materials (Howard 2013). Additionally, repurposing decommissioned shipping containers is a more sustainable pathway to the typical approach of dismantling them for their materials. A study found that dismantling a single TEU shipping container and convert it into raw material, requires 8,000 kWh of electrical energy compared to 400 kWh to converting the same size container into a house (Hammond et al. 2008; Islam et al. 2016). Most research on repurposed shipping containers focuses on design aspects. There is a clear research gap on the sustainability potential of such structures more specifically in life cycle assessment (Islam et al. 2016). A life cycle assessment can showcase the sustainability potential of extending the life cycle of a shipping container.

3.2.3. Vacant land assessment

In addressing the sustainability of the urban environment, the overwhelming consensus in the literature indicates that the complexity of urban systems and the lack of a clear assessment approach are two key hurdles (Mirabella et al. 2019; Mirabella and Allacker 2017). There are several guidelines for the assessment of urban environments, however, they focus on environmental impacts. Most life cycle assessments in the built environment sector focus on building products. Consequently, most assessments address the cumulative effects of products that make up the end system (typically a building or group of buildings). On the other hand, there is a lack of implementation of LCA at an urban scale (Lotteau et al. 2015). Research indicates a lack of consensus on the parameters that make up an urban system. These disparities pertain to the system's function, functional unit, reference flows, and boundaries (Lotteau et al. 2015).

In addressing this issue, several indices were developed to assess urban sustainability based on either environmental, economic, or social factors (Mori and Christodoulou 2012). The benefit of these indices in their ability to define and standardize urban parameters to establish unified scoring tools. These indices use urban-based indicators; however, most are single-impact approaches (Albertí et al. 2018). Most urban based indices focus on one aspect of sustainability. In fact, some were custom developed to assess a specific city or region based on site specific indicators (Petit-Boix et al. 2017). As they represent local conditions, these indices are good reference tools but are hard to work with unless they are used for regions with identical or very close characteristics.

Additionally, most approaches rely on indicators related to production and consumption patterns at an urban scale. An observation of key urban assessment approaches highlights a lack of consensus with regard to defining urban boundaries (Albertí et al. 2018). This is mainly due to the fact that urban processes are affected by contexts. This makes a product-oriented tool such as LCA potentially suitable for urban assessment. However, there is not yet a holistic LCA application for an urban environment (Petit-Boix et al. 2017). Most applications are sector-based or limited in geographical scope.

This paper examines an LCA model based on a multi-system lifecycle assessment which compiles impact categories of vacant lands on the one side and impact categories of shipping containers on the other side. This model utilizes existing themes available in the literature to identify a system model and areas of impact. The motivation for this manuscript includes:

- Addressing the lack of knowledge regarding integrated LCA approaches.
- Investigating the potential for compiling two streams of LCA to evaluate urban regeneration.

- Exploring opportunities for determining the performance capacity of shipping containers as building units in an urban environment.

3.3. Methodology

Life cycle assessments are valuable tools for the investigation of relationships and frequencies of concepts that define an observed system. Research showcases some of the trends in applying LCA methods to urban systems. These trends highlight differing goals and scopes in urban assessments that are driving some of the methodological challenges in urban assessment research (Lotteau et al. 2015). One reason is that defining an urban system is not an easy task. Since there is no one way to define them, they can be described geographically, sectorally, or temporally. Another reason is that urban systems are complex, as they can vary in scale, function, and provision (Petit-Boix et al. 2017). Some of these trends include attempts to expand its application to urban systems of varying scales and compile it with other established methods such as Urban Metabolism (UM), Material Flow Analysis (MFA), Environmental Risk Assessment (ERA), and others (Mirabella et al. 2019). These methods are top-down approaches and benefit from having limited geographical restrictions (Albertí et al. 2017). On the other hand, bottom-up urban LCA approaches are limited in scale, however, they deliver indicator guided assessments that focus on specific impacts (land use, water, waste, … etc.). A Number of studies investigate hybrid methodologies that compile urban approaches to life cycle assessments. This provides an opportunity to propose an assessment framework that fills a gap in urban LCA by exploring Multi-System Life Cycle Assessment (MSLCA) model.

The proposed MSLCA framework combines different methodological approaches with the aim to address the multi-dimensional characteristic of the problem. Mainly, the model is structured around the stages of conventional life cycle assessment standards to connect two systems across shared assessment parameters. In general, life cycle assessments follow four main stages that include 1) goal and scope definition, 2) inventory analysis, 3) impact assessment, and 4) life cycle interpretation (Baumann and Tillman 2004). The goal and scope definition stage defines the product system for the life cycle assessment. The inventory analysis stage specifies the system's processes through the identification of flow diagrams with unit processes, and the collection of data for each process. The impact assessment stage calculates the impact of the product system. Finally, the interpretation stage synthesizes the assessment results of the system.

The goal is to propose a value-based approach to assess temporary urban regeneration based on characteristics from two system streams. This is to take advantage of an existing method in order to build knowledge on standardized approaches for urban assessment. This is a departure from available research on urban systems which typically utilizes case-specific assessment approaches. However, the model is set up to address key parameters of the two systems to define baseline performance indicators of both and describe key attributes for decision making. Through mapping processes and matching patterns of the two systems, the model helps create benchmarks that provide backing to temporary urban regeneration decisions. These decisions pertain to: 1) the appropriate use case to the site; 2) the appropriate transformation process; and 3) the appropriate end-of-life scenario.

3.4. Analysis

The main objective of the MSLCA model is to establish a framework to assess mutual impacts of two systems, which, within this paper, is observed through opportunities of temporary urban regeneration. The analyzed system pertains to short-term urban interventions on vacant lands using shipping containers as temporary structures (Figure 27). The model helps create a specific use case, select indicators for assessment, and study reference flows relevant to the system. It brings together separate parameters to define impact categories relevant to both life cycle streams. The model is proposed to investigate the application of life cycle assessment to literature observed issue that is made up of two separate systems. This issue inspires an opportunity for a temporary urban regeneration system that uses shipping container structures on vacant lands. By analyzing case specific temporary urban intervention, the model provides an assessment framework to support literature explored urban regeneration goals. These goals can be summarized into, a) accelerating urban change through resilient processes of change; b) increasing land use functionality by creating new uses on available infrastructure; and c) enhancing livability by revitalizing urban identity.

Figure 27. Schematic visualization of the urban regeneration system analyzed

3.4.1. Interest areas

Decisions on assessment parameters are guided by literature documented urban regeneration interest areas. A review of the literature conducted for the purpose of this research divides interest areas into environmental, economic, and social categories (See Chapter 2). Environmental interest areas include material use and land and resource protection. Economic interest areas include value related impacts, cost effectiveness, and contextual economic effects. Social interest areas include education, users' needs, participation, and social capital. Additionally, urban interest areas were observed and documented which include land use functionality, urban identity effects, and urban resilience. Interest areas are key in informing the impact categories for the assessment and the connections between life cycles while also considering the local urban context to inspire appropriate site-specific use.

Given the established interest areas for temporary urban regeneration, the model refers to the literature to determine key parameters for the assessment which include site, use, and impact indicator parameters. Site parameters address the site's type, size, and location. According to research on temporary urban regeneration, 64% of the reviewed literature study vacant sites. Use parameter, on the other hand, addresses interventions type, duration, and goals. The review of the literature categorizes temporary use types into community spaces, urban agriculture, natural spaces, commercial spaces, and urban services. The review also concludes that over half of the observed use cases are designed to serve as community spaces with overwhelmingly environmental (34%), social (30%), and urban (29%) impact indicators used in their assessments. The reviewed community spaces were divided into four space types, which include; open space, social space, entertainment or event space, and workspace (See Chapter 2).

3.4.2. Connecting life cycles

By observing the assessment parameters, the model establishes connections between the two separate systems using contextual relations to determine the appropriate stage of life cycle connections. Studying both systems' life cycles helps in understanding the stages that represent their service. Through the investigation of both life cycles, the model identifies a point of intervention as an appropriate "Opportunity Stage" for cross-system convergence. This point is determined to be the ideal phase of both cycles (Figure 28). The Opportunity Stage can be observed at different phases of each of the interconnected life cycles. This connection requires a tool to build a use case for the life cycle assessment. Additionally, the advantage of a temporary urban intervention is that it creates a new system without significant alteration to the primary systems.

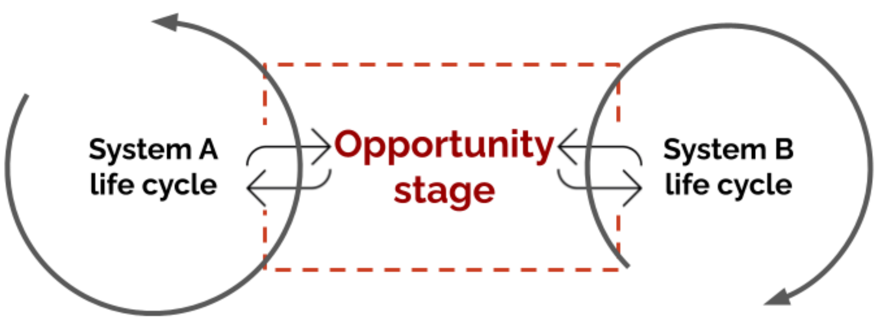

Figure 28. Life cycle connection between the two systems to determine an "opportunity stage" for the temporary urban intervention

3.4.3. Opportunity matrix

The here developed process examines documented literature parameters for temporary urban regeneration to create an opportunity matrix of intervention scenarios and an overall system design. The matrix cross references literature interest areas in temporary urban regeneration research with documented research indicators (Table 3.4.1). This is to guide decisions regarding the assessment focus based on environmental, economic, social, and urban categorizations. The matrix also helps in selecting an appropriate use case for the assessment. Through documenting use cases addressed in the literature, the matrix is used to match assessment parameters to appropriate temporary use cases. Additionally, the model extends the utility of the matrix to make decisions regarding the degree of intended alteration on both system streams. The collected site characteristics which include: type, size, duration, and ownership status. The goal of the matrix is to plan literature informed scenarios that include key parameters for the assessment (Figure 29).

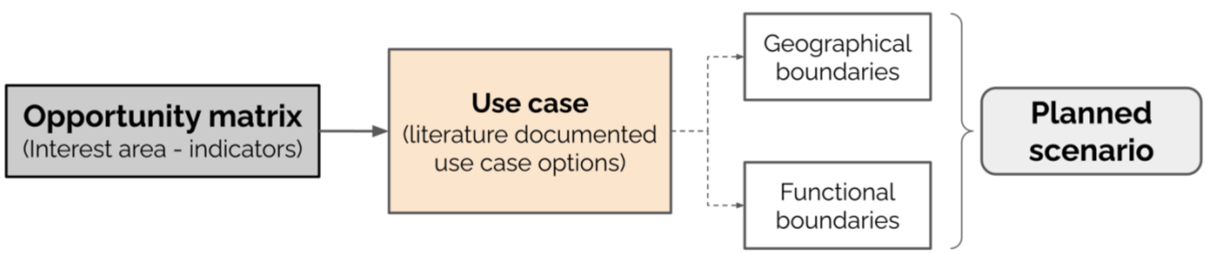

Figure 29. Opportunity matrix utilization process to determine the planned scenario for the assessment

The model matches a planned scenario created for the assessment with project services that best fit the objectives of the assessment. The scenario integrates the two system streams based on elements that layout decisions that describe the specifications of the urban intervention. The scenario also defines the system's boundaries which compiles information about the two systems. In such a multi-stream system, the boundaries are separated into; a) geographical boundaries which determine the physical limits of the urban area under study, and b) functional boundaries which determine the activities impacting the system. Generally, in an urban system, most impacts occur beyond the geographical boundaries which increases the complexity of the system. Therefore, the model establishes system boundaries based on the provision of set services. Service-based boundaries consider impacts related to activities that provide a service within the geographical or functional boundaries. This approach enables the life cycle assessment model to establish realistic boundaries in terms of their influence on sustainability.

Table 3.4.1 Opportunity matrix for the MSLCA assessment model

Opportunity Matrix:		**Interest areas**															
		Environmental				Economic			Social					Urban			
		Environmental protection	Green space	Resource use	Land use	Value impacts	Cost & benefits	Econ. context	Participation	Education	Access	Social impact	User needs	Patterns of use	Functionality	Supporting services	Context & proximity
Indicators	Environmental	●●●	●●● ●●● ●●	●●● ●●●	●●● ●●●	●●	●●	●●	●	●●	●	●●●	●●	●●● ●		●●● ●	●
	Economic		●●● ●	●●	●●	●●● ●	●●● ●	●●● ●			●●	●●● ●●	●●	●●			●
	Social		●●● ●	●●	●●	●●● ●●●		●●	●●● ●	●●	●●● ●●●	●●● ●	●●● ●	●●● ●●●	●		
	Urban	●●●	●●● ●●●			●●		●	●●● ●	●●		●		●●● ●●●	●●● ●●●	●●●	●●

3.4.4. Life cycle inventory analysis

The here modeled process requires the user to create a specific use case, study appropriate parameters for assessment, and then select impact categories relevant to the system. It brings together separate parameters to define reference flows of both systems. Applying the model to such assessment helps determine a holistic impact of temporary urban regeneration based on environmental, economic, and social parameters (Figure 30). Consequently, the selection of relevant impact categories is key in assigning flows from the inventory to the impact categories. These parameters can be categorized into:

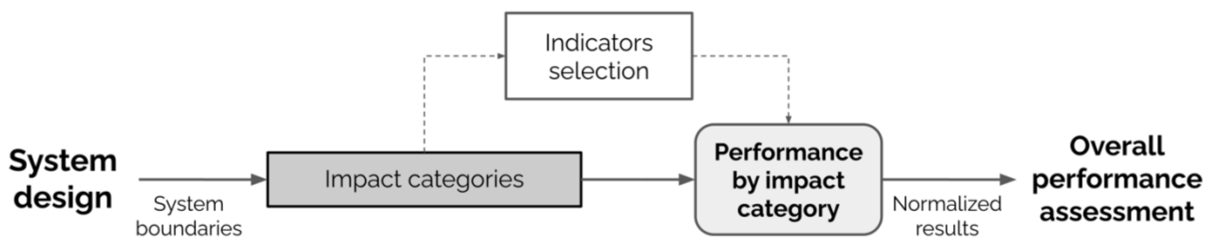

Figure 30. Life cycle inventory analysis process

- **Environmental assessment of land use,** which considers the impacts associated with occupying the land. Land use impacts pertain to the environmental effects of materials used to establish the use case. Contextualization is applied for typical local construction processes and material options. Generic data are used for representative impact values of material categories.
- **Environmental assessment of resource use,** which addresses the environmental impacts of material use for the intervention; mainly the repurposing of shipping containers into structural units. Data for material input (consumption) and output (waste) are aggregated through independent contractors' input. Any missing data are supplemented by classified reference studies.
- **Economic assessment of costs and benefits,** which assesses the monetary cost to establish the use case by conducting a cost assessment of repurposing shipping containers into structures. Based on identical design specifications, market data are gathered from independent contractors on the cost of shipping containers' conversion and conventional construction to determine the cost-effectiveness of the proposed system.

- **Economic assessment of property value,** which addresses the fluctuation in land value throughout the intervention's life cycle. Through an investigation of historical market data, the analysis populates financial data on changes in land prices within 5 minutes walk (400 m) of the intervention site. The findings guide projections into the immediate future of land value at the end of the life cycle. The findings are compared to reference property value data of temporary land use research.
- **Social assessment of users' access**, which addresses the utility of the intervention by assessing changes in users' access during temporary urban interventions. The assessment considers reference research on applicable infrastructure improvements such as the availability of sidewalks, lighting, shade, seating areas, parking, bus stops, and others on altering users' behavior. Key data points include population count, density, location, and proximity.

3.5. Results

The model approach developed within this paper for conducting a MSLCA was applied for two very specific life-cycle systems, the highly versatile system of shipping containers, and the much more stagnant system of urban land use. Generally, in an urban system, most impacts occur beyond the site's boundaries (Albertí et al. 2018). This increases the complexity of the assessment, especially in a multi-system approach. The model follows established LCA steps to create a process for multi-system integration. The resulting proposed model adopts the following stages (Figure 31):

- **Exploring problems and opportunities:** At this stage, the model explores the aspects of a problem as it relates to the two systems that are investigated. The objective is to highlight potential opportunities where systems act together to create a joint system or a product that provides a solution to two otherwise separately observed problems. Decisions on appropriate opportunities are guided by documented interest areas in the literature based on pre-determined categories.
- **Parameters for system integration:** At this stage, the model refers to the literature to determine key parameters to guide the assessment model. The parameters address observed

indicators and how they relate to the processes of the system. This requires the utilization of systematic literature review to extract relevant data. In this case, data on temporary urban regeneration are used to establish connections between the two systems based on literature observed parameters.

- **Opportunity matrix:** During this stage, the model inventory is searched for the most common attributes of temporary urban regeneration. This is achieved by examining literature to highlight its key assessment indicators, project services, and use cases. The objective of this stage is to create a matrix from which system boundaries can be drawn. The goal is to evaluate options in order to build system components for the life cycle assessment. The opportunity matrix categorizes literature findings and other related parameters to create assessment scenarios.
- **Plan scenario and system design:** Given the complexity of the system, the model uses the opportunity matrix to help plan a scenario for the system. The scenario provides a comprehensive description of the system to create an overall system design. The design address parameters that match the two system components. It highlights processes and specifications that describe minimum requirements that enable the proposed scenario to function. The system design provides a unified basis for comparison by which inputs and outputs are determined.
- **System assessment approach:** The model proposes an inventory analysis procedure for collecting source data, ensuring the completeness of the inventories, and tracking related flows in and out of the system. The input and output data are modeled based on the specific system and its life cycle processes. Process-specific data are contextually gathered while reference data are inventoried from relevant research. The model utilizes selected assessment indicators to score the system per impact category and determine its overall performance. The goal of the model is to aggregate the impacts of the systems into a total impact score.
- **System interpretation approach:** The model suggests an interpretation process that addresses interdependencies between the selected indicators to assess their potential impact on the system. It allows for consequential modeling to help identify the consequences of decisions in the system to other processes. Additionally, the assessment approach represents impacts in terms of comparable scale using characterization factors to allow it to be assessed based on relative categorization. For that, a cross-system functional unit is suitable to connect and compare impact categories in terms of a common unit to transform non-comparable systems

into compatible values based on a unified scale.

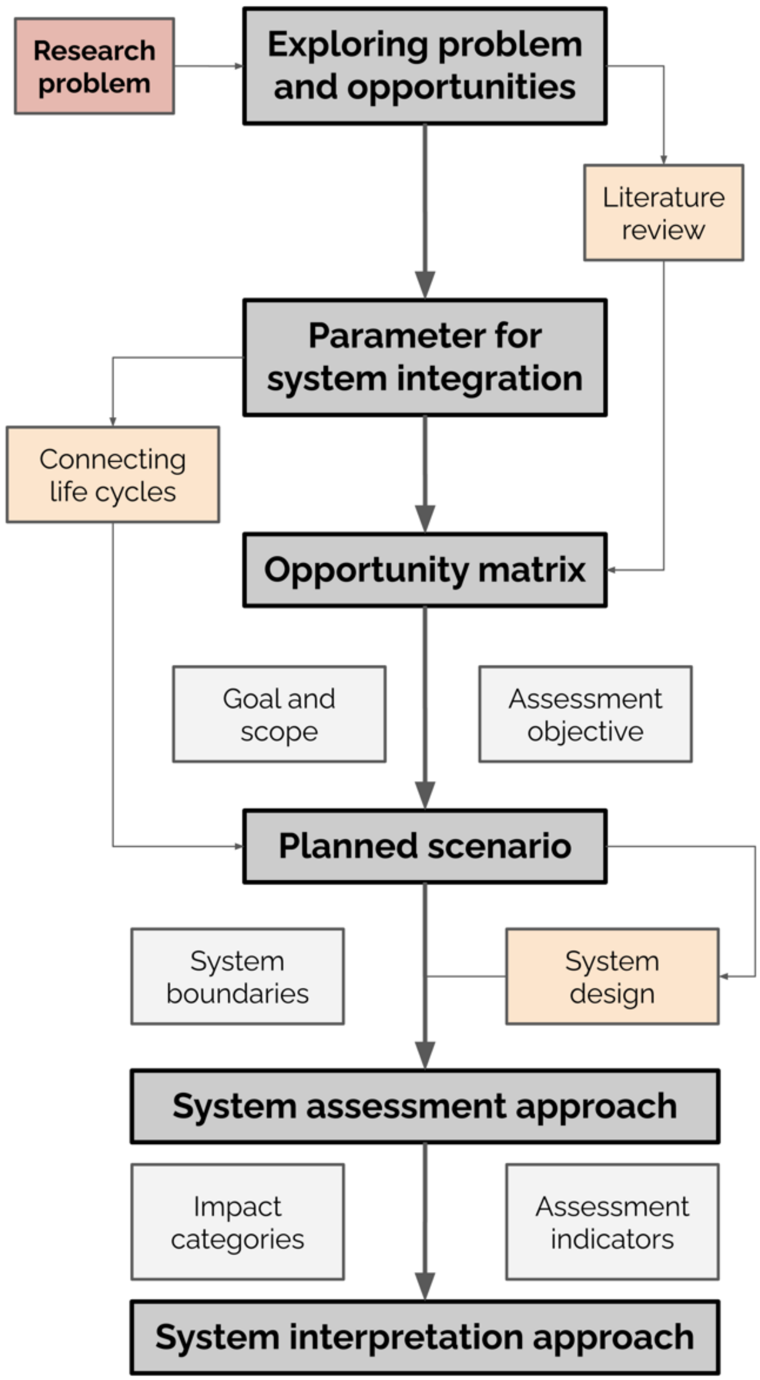

Figure 31. Process diagram for proposed Multi-System Life Cycle Assessment (MSLCA) model

3.5.1. Connecting systems

In order to connect two separate systems, the MSLCA model highlights an opportunity stage at which two system streams intersect to create a temporary product that draws value from both systems (Figure 32). The model considers the opportunity stage as an idle phase in both systems and where a full system can be created. For example, in the case of vacant land, an opportunity stage concerns lands in developed subdivisions with infrastructure and where a degree of surrounding uses is established. In the case of shipping containers, this stage concerns decommissioned containers that are not suitable for cargo transportation and are waiting to be dismantled for their materials or to be used alternatively. At this point of both cycles, the intervention extends the life of shipping containers and utilizes valuable assets such as lands that have not yet reached their full potential.

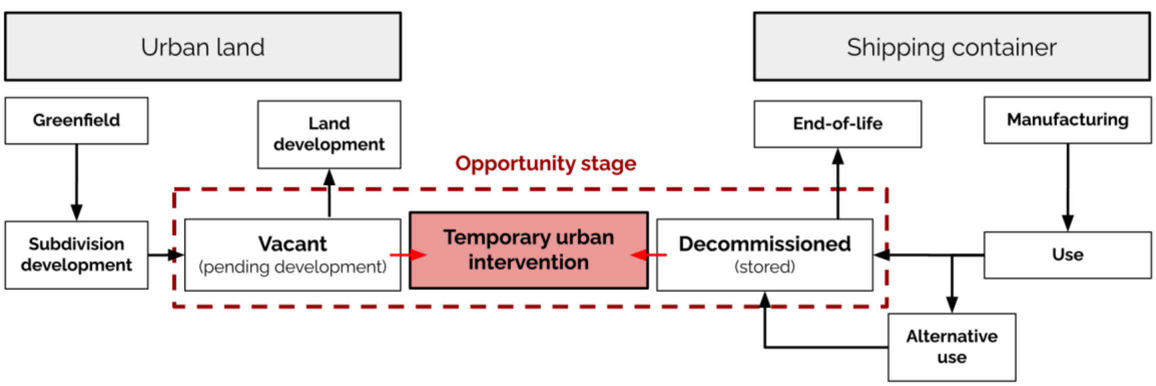

Figure 32. Systems connection at the opportunity stage for temporary urban intervention

3.5.2. Base scenario

The MSLCA model used establishes a base scenario for the proposed intervention based on parameters extracted from the literature. It uses the opportunity matrix to help plan a scenario for the system. The scenario provides a comprehensive description of the system to create an overall system design. The design address parameters that match the two system components and highlights specifications that describe minimum requirements that enable the proposed scenario to function. It lays out the system's design to highlight the intervention scope as it relates to the site and structure. The site design describes the urban intervention and provides specifications on materials used, their quantities, and sourcing information. The structure design describes the alternate use case for the shipping container by providing design and construction specifications. Also, site specific parameters are taken into account to address contextual aspects of both systems. Therefore, the base scenario integrates the two systems based on common elements. These elements are meant to help design the assessed system. The introduction of a base scenario helps in determining appropriate case options to showcase the value of the proposed intervention. The advantage of using a base scenario is that the assessed options are addressed with regard to the activities and impacts affecting the proposed temporary urban intervention system. The premise of the adopted approach to urban regeneration is that it produces value from underutilized resources. This is analogous to extending the life of a product or a system. In doing so it creates a new system without significant alteration to the primary systems.

3.5.3. System boundaries

The boundaries have to be compiled from relevant information from the two specific systems based on contextual and functional boundaries. The contextual boundaries determine the characteristics of the urban area under study which includes the physical limits and conditions of the site. The functional boundaries determine the activities of the system which include the life cycle phases and related inputs and outputs. This approach enables the life cycle assessment model to establish realistic boundaries in terms of their influence on sustainability. For example:

- **Contextual boundaries:** To demonstrate the application of this integration, the here integrated system is geographically located in the city of Riyadh, the capital city of Saudi Arabia. More specifically, the system is situated in an inner part of a residential subdivision which typically suffers from a lack of urban services. These parts are often lower in density and characterized by a high prevalence of vacancies. The site selected for the assessment is located in a northern subdivision of the city. This part of the city is a recent expansion to the urban fabric and is in the process of development. Therefore, most of the urban landscape is characterized by vacant lands. Within this neighborhood, there is a site of 1,000 m^2 vacant land with barely any distinct typographical or natural features. The site sits between single-family homes and is open from three directions while bordering to two residential units along the fourth side (Figure 33).

Figure 33. Possible site for a temporary urban intervention

- **Functional boundaries:** The functional boundaries of the system concern the life cycle functions for the assessment scenarios. The functions are established around use case processes and cover their related inputs and outputs. It mainly addresses the urban regeneration potential of the assessed use cases and their ability to produce value from it (Figure 34 & Figure 35).

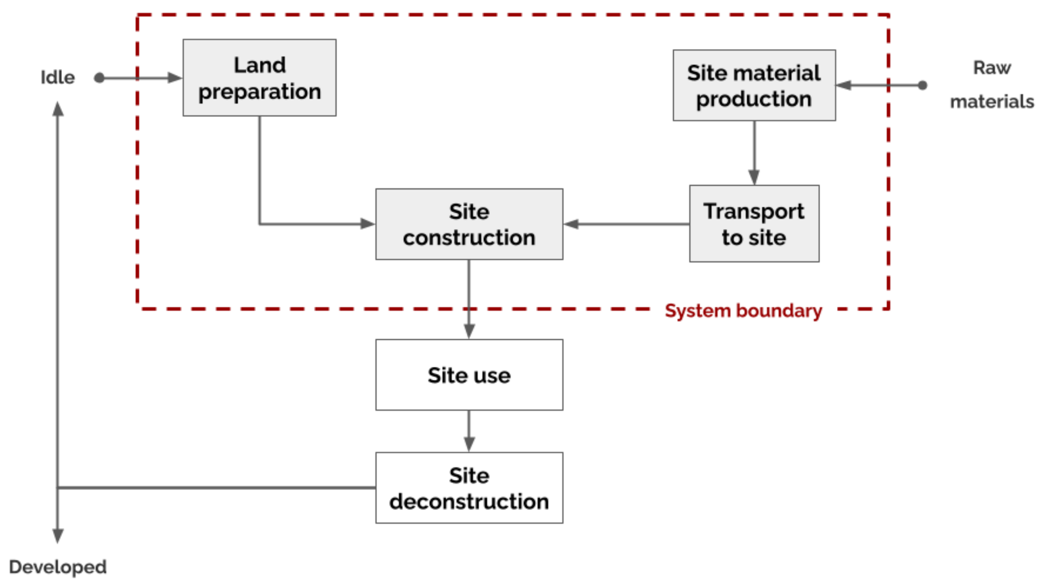

Figure 34. Land system boundaries

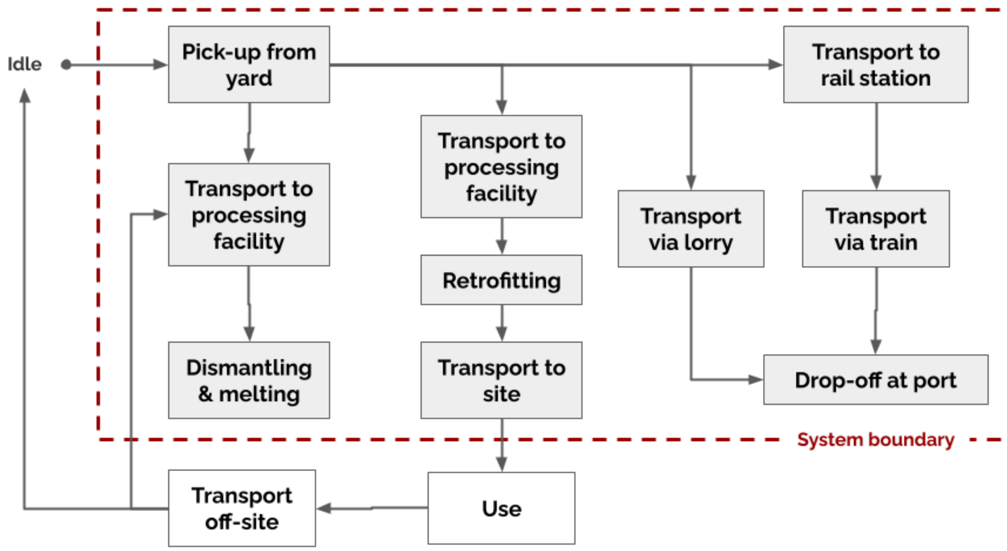

Figure 35. Shipping container system boundaries

3.6. Discussion

Temporary urban regeneration consists of three key elements which include space, uses, and users. The interaction between these elements highlights the complexity of the provisional use of space. Such complexity is a product of abroad number of system parameters which creates a wide range of different urban intervention options. This is evident through the breadth and ambiguity of the literature on the development and assessment processes of temporary uses. The proposed MSLCA model attempts to establish a multi-system life cycle assessment framework to assess a transient urban regeneration system that is made up of two separate life cycle streams. The model is a response to an increasing need for a comprehensive urban LCA tool at the micro-level. Applying a life cycle assessment approach at an urban intervention scale allows for connecting unrelated systems that contribute to temporary urban use. This is achieved through the identification of overlapping flows and establishing correlations between the systems to address an observed problem and to assess the cumulative influence of the systems on sustainability.

In order to address all three elements of temporary urban regeneration, the MSLCA model extends beyond assessing environmental impacts and also tried to address economic and social effects. This raises a contextualization challenge for the assessment. Therefore, the model ensures that intervention specifications are determined at the goal and scope definition stage. This includes related land use functions to enable relevant propagation of inventories. Additionally, spatial variabilities between different interventions serving the same function could raise similar challenges. Therefore, the representation of accurate spatial information throughout the stages of the assessment is important for getting valid results. This is where the role of the planned scenario becomes imminent which requires a consistent description of the system. The utilization of an opportunity matrix that is backed by systematically aggregated literature data helps the model to be spatially explicit. Consequently, the decisions of planned scenario can be tailored to the context of the intervention and not only its function.

Another challenge is that in an open urban system, boundaries are hard to be accurately allocated. This could hinder the system's boundary definition process on the urban side due to the broad range of activities that innately make up an urban system. By utilizing the literature to inform key parameters, the MSLCA model sets boundaries for the system components that can react to previously set objectives of the assessment. Mainly, the ephemeral aspect of the intervention determines the perimeter of the impact categories and the indicators used in the assessment. This raises a question regarding a challenge of shifting burdens to impact categories that are not incorporated in the assessment. This is mainly a drawback of localized data availability. To minimize uncertainties in process data, the model uses local sources to populate site specific data; while reference data are inventoried from relevant research. This allows for consequential modeling which helps identify the consequences of a decision in the system on other processes. In doing so, relevant inventory data are used to assess the impacts of system flows and then compared against potential effects on other impact categories. This is to minimize the disadvantages of data availability; thus, the need for such a highly customizable assessment tool that enables both qualitative and quantitative data. Additionally, normalization factors are especially necessary in this case to allow for unified units in cross-categories comparison.

The MSLCA model can also be useful in setting benchmarks for comparison against other system options. In order to showcase the value of a proposed intervention, an assessment can analyze the planned scenario along with two intervention options. Such options can pertain to low impact alternatives of a no-development scenario and potentially a high impact option of a permanent development scenarios. Additionally, the results can be applied to a wider range of indicators to anticipate corresponding improvements to either systems. Future research can add value by expanding the use of the mode to other impact categories to effectively predict longer term impacts of temporary land use beyond the intervention's time frame.

3.7. Conclusion

Vacant land development is a broadly used approach for temporary urban regeneration. This paper proposes a framework that attempts to assess temporary urban regeneration based on documented literature practices through the implementation of cross-system LCA to facilitate a comprehensive assessment of urban regeneration. A number of lifecycle-based methodologies exist to assess the urban environment; however, they lack a holistic approach in addressing impacts in a comprehensive manner across systems used for regeneration. Considering that urban systems are one of the most complex systems, addressing environmental impacts only highlights part of its effects. Incorporating economic and social aspects in a holistic framework paves the way for identifying broader sustainable practices in urban development.

With a focus on urban land vacancies and resource reuse, a proper definition of the system is key. The here presented model relays data from literature to inform the system's boundaries by highlighting transboundary processes between the two system streams. The model addresses the effects of activities relating to temporary urban interventions on vacant lands using shipping containers as structures while considering both production and consumption perspectives. The model informs the requirements for specific assessment indicators to acknowledge the multifunctionality of a multi-stream urban system.

Ultimately, the model can act as a decision support tool for temporary urban regeneration. This tool is designed to address impacts in a more holistic way, identify hot spots where most impacts occur in a temporary urban system, and assess and compare temporary urban interventions that could introduce sustainable solutions.

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Chapter 4 – Manuscript Three

A multi-system life cycle assessment using shipping containers as a means for temporary urban regeneration on vacant lands

Target Journals:
Environment and Planning D: Society and Space (https://journals.sagepub.com/home/epd)
Urban Geography (https://www.tandfonline.com/journals/rurb20)
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4.1. Abstract

Temporary urban interventions are considered a sustainable short-term management strategy for vacant lands. Several temporary use approaches exist to utilize unproductive urban spaces. Most research focuses on regeneration techniques that address the use rather than the tool. This research addresses inefficiencies in two, initially independent, systems that can be joined in an urban intervention to provide temporary urban regeneration objectives. Specifically, the accumulation of decommissioned shipping containers at inland storage depots, as well as, the prevalence of vacant lands within the urban boundaries in Riyadh, Saudi Arabia have been identified as an opportunity to explore such an intervention. This paper demonstrates the application of a Multi-System Life Cycle Assessment (MSLCA) model. In order to estimate the effective sustainability of temporary urban interventions, a comparative multi-system LCA has been conducted. The assessment focused on environmental indicators of Climate Change (CC), Acidification Potential (AP), Ozone Depletion (OD), Water Use, and Resource Use. To ensure a reliable assessment, a functional unit describing the product system of all systems involved is established. For a comprehensive comparison, use case scenarios of potential systems pathways are assessed. The results highlight the environmental advantages of extending the life of shipping containers through repurposing while mitigating some of the negative impacts of land vacancy. The model presents a potential for merging systems to create value from their influence in tackling a different practical problem. Future research can extend the application of the model beyond assessing environmental impacts to evaluate economic, social, and urban effects.

Keywords: Life cycle assessment; Shipping containers; Temporary urbanism; Urban regeneration; Vacant land.

4.2. Introduction

Cities are in a constant state of change. The process of urban development is inherently conducive to regulatory mandates, economic changes, and social powers. Generally, urban developments bring positive impacts to an area. It can also encourage underserved urban expansion. Urban sprawl in particular is a product of planning policies centered around urban growth. Urban growth at its core is a series of processes that reshapes the urban landscape. Such processes are incremental and temporal by nature. A common feature of such changes are urban vacancies. These unproductive areas pose key challenges from perceived blight to potential crime proliferation (O'Callaghan and Lawton 2015; Francis 2012). Yet, they can also be a valuable source for urban regeneration. Vacant land carries here a significant potential in its capacity to provide regeneration opportunities. The barriers to initiating vacant land developments are much lower than revitalizing vacant structures or brownfields. This is specifically true if such regeneration goals are short-term.

This research aims to support such scenarios by utilizing a specific Multi-System Life Cycle Assessment (MSLCA) model to evaluate the environmental effects of temporary urban regeneration. This model argues that addressing urban vacancy through this lens can help unveil untapped potentials of alternative utilization. This has the prospect of making use of a significant amount of vacant land often left unutilized. The model suggests that integrating urban vacancy with a complementing life cycle stream into a temporary system could help highlight the unseen value in both systems. By establishing an assessment framework of temporary appropriation in this vein, the model enables temporary use cases for vacant lands that are LCA based and showcases ideas of circular economy. The overarching sustainability objective of circular economy is to enable systems to regenerate themselves by limiting inputs of material through reuse in successive utilization cycles, as well as, managing outputs of waste (Charter 2018).

4.2.1. Vacant lands

Vacant lands are a product of urban development. Such sites include unused greenfields, brownfields, or abandoned structures within the urban boundaries. The amount and condition of vacant lands vary by region due to economic, regulatory, or social conditions (Newman et al.

2018). In the city of Riyadh, the highest estimate by the Royal Commission for Riyadh City recognizes 40% of the area within the urban growth boundaries as undeveloped. Such prevalence of vacant lands has negative impacts that include the allowing for disinvestment, and enabling fragmentation to the urban fabric (Gamboa 2008). Understanding the conditions underpinning this type of urban voids in Riyadh is key in determining the path for appropriate interventions. Generally, the development of vacant lands requires community demand and political will, as well as, a significant investment of time, infrastructure, and money (Bowman 2004). All these create barriers to vacant land development. This presents an opportunity for a temporary approach to vacant land development.

Temporary developments offer tailored solutions capable of circumventing conventional barriers (Bishop and Williams 2012). Vacant lands play a major role in temporary urban regeneration. The notion of recognizing such lands as sites for regeneration allows stakeholders to innovate in experimenting with solutions that create value from unproductive sites. These sites can be transformed through sustainable strategies into spaces that serve urban regenerative goals. (Pagano and Bowman 2000). However, not all vacant sites are the same, there are underlying socio-economic conditions. Some of these conditions are site-specific which increases the tension of the issue. The complexity of site conditions and socio-economic conditions poses challenges to the tenure of vacant land use.

4.2.2. Shipping containers

The use of standardized shipping containers enabled unprecedented efficiencies in global trade. These intermodal units facilitate the movement and storage of goods throughout the supply chain. However, any trade imbalances can over time cause significant displacements of these units. This is particularly an issue for import-oriented regions as empty containers could be uneconomical to ship back. In fact, the transport of empty containers back to their origin is in some cases as costly as producing a new one (Slack 2013). This causes these containers to sit idle at storage depots and be taken out of circulation. Some research estimates over 2.5 million shipping containers are sitting idle around the world (Karmelić et al. 2012).

The surplus of empty containers inspires innovative approaches to repurpose such a versatile resource in creative ways. The alternative uses of shipping containers take advantage of their modular shape, rigid structure, and overall design. This has a major environmental benefit of minimizing new resource extraction. This idea aligns itself with the concept of a circular economy where resources are circulated within a system to reduce the environmental impact (Foster 2020). Research provides little information regarding the environmental advantages of repurposing shipping containers. For temporary use, a multi-system life cycle assessment approach is suitable to provide a decision-making tool for container reuse for temporary urban regeneration.

4.2.3. Temporary urban regeneration

Temporary urban regeneration focuses on creative solutions that provide a wide range of activities capable of unlocking the potential of neglected or underutilized spaces. The redevelopment of these spaces can reverse the negative effects of blight, disrepair, and any associated hazards that could be a risk to health or safety (Mahmoudi Farahani and Maller 2019). In fact, most research centers around the main advantage of repurposing these spaces which is to transform them into productive urban assets as appose to potential liabilities (Burkholder 2012). Temporary uses are seen to make good use of neglected spaces and turn them into usable spaces. Such spaces can be established on a temporary or permanent basis to address the socio-economic conditions of the site. They can also provide opportunities for responsible sustainable improvement and optimized environmental performance across systems (Gasperi et al. 2016).

Benefits of temporary urban regeneration. Research highlights broad advantages that result from particular temporary uses. A review of temporary urban regeneration literature highlights several studies, which encourage the sustainable utilization of vacant or abandoned spaces into green parks based on observed ecological, social, and economic benefits (See Chapter 2). Sean Burkholder summarized these benefits to residents, the city, and the broader region (Burkholder 2012). Residents benefit from proximate access to nature; a valuable opportunity for recreation and environmental education. They also benefit from new job opportunities and can realize a unique neighborhood identity. The city, on the other hand, benefits from the positive effects of supporting, regulating, and provisioning ecosystem services. The city can also benefit from lower infrastructural management costs and opportunities to create more dense and livable opportunities. Additionally, by redeveloping derelict sites into natural spaces, the region can improve its biodiversity and better connect its ecological, cultural, and economic networks to the larger regional infrastructure (Kamvasinou 2011).

The literature praises the benefits of rehabilitation of natural spaces in permitting ecosystems to coexist in an urban setting and allowing for rich spaces to develop. Regeneration of vacant sites into natural spaces falls under the categorization of 'reverse status' development (Petríková and Szuhová 2017). Most temporary urban regeneration interventions of this kind are low impact and require minimal alteration to the land to create ecologically diverse spaces (Kamvasinou 2011). Additionally, improving connectivity is a reoccurring theme of inquiry in urban regeneration. A study of the ecological potential of developing vacant land into greenspace analyzed the benefits of linking habitats (Newman et al. 2017). The study utilized a least-cost path connectivity model to evaluate the ecological value of vacant land development. The findings revealed their potential for high ecological value in creating ecological corridors and enhancing the provision of ecological services with minimal negative impact.

Temporary commercial spaces, on the other hand, offer unique regeneration opportunities capable of achieving advantageous economic, and social goals. Temporary commercial uses are a key tool for urban regeneration. It stimulates economic activities and attracts newcomers to the area. It can bring needed retail activities to the area, allow business owners to expand, and provide new revenue streams to the city (Ziehl and Oßwald 2015). These spaces provide an attractive business environment for small entrepreneurs to test their ideas as it provides low-cost access to the market. Typical commercial uses usually exclude entrepreneurs with low budgets or minimal resources. Several articles refer to the influence of business owners activating temporary commercial spaces. By participating in the development process, these business owners can influence the design of the area (Ziehl and Oßwald 2015). This, since most documented cases reveal that business owners are also community members, ensures that most business and design decisions are tailored to the users' needs.

Research also highlights some of the social benefits of temporary urban regeneration, specifically, the benefits of urban regeneration through food production. In addition to its advantages in regulating environmental services such as improving air and water quality, stabilizing soil, and reducing pollution (Calvet-Mir and March 2019), the main benefit research focuses on is ensuring food security in urban areas that lack access to fresh healthy food. A number of studies found that mitigating food deserts can have a wider impact on improving the health of residents (Carlet et al. 2017; Rhodes 2012).

Approaches to temporary urban regeneration. The literature recognizes two approaches to temporary urban regeneration. The first is top-down supported and funded by local municipalities. This approach utilizes the assets and experiences of the local government to allocate resources and make necessary policy decisions (Carlet et al. 2017). Some of the key challenges to this approach are the availability of upfront investment, the lack of a clear definition of the roles and responsibilities of stakeholders, and the integration with the existing urban system (Petríková and Szuhová 2017). The second is a bottom-up approach characterized by self-organization. This approach relies on engaging the public through participatory processes to meet the community's exact needs. Some of the challenges to this approach include policy, land access, and long-term feasibility, (Hou and Grohmann 2018).

These two approaches serve different goals, however, as it all comes down to management and access. Most research on temporary urban regeneration implies that the ideal management authority for these spaces should be the responsibility of volunteers or civic community-based organizations (Carlet et al. 2017). Research argues that public entities, on the other hand, should be responsible for admissible policy decisions, land access, and other appropriate municipal interventions. Therefore, defining a relationship between these two elements can help design innovative solutions. Such solutions can benefit from being context-sensitive and process-driven (Lokman 2017). Additionally, the nature of temporary use attracts the type of user who is interested in that type of use, therefore, such temporary uses could unwillingly deny access to some community members. In order to ensure universal access to these sites, research points out the importance of building social capital through engagement and education to better serve the community (Gasperi et al. 2016).

Challenges to temporary urban regeneration. The nature of temporary development poses a number of challenges. Research highlights funding and policy as two main challenges to temporary commercial spaces (See Chapter 2). Establishing a sustainable funding model complemented by a flexible policy framework is a reoccurring recommendation in most studies. Due to the temporary nature of these uses, not all investments are suitable (Martin et al. 2019). Some high-cost investments can be risky and require a longer timeframe to bring acceptable financial returns. This diminishes the options for the types of realistic commercial ventures. Additionally, with limited use options and without a clear policy framework for most regeneration initiatives, temporary uses by themselves would struggle to be an attractive proposal for stakeholders. Therefore, research on urban regeneration emphasizes the need for a set of sustainable policies that can create a competitive advantage for the site (Carlet et al. 2017). For policymakers, such interventions are creative low-barrier tools for promoting urban sustainability. It can become an integral part of the wider sustainable urban infrastructure. For example, an evaluation of urban gardening initiatives in Barcelona reveals their outcome in lowering the green infrastructure deficit by increasing the per capita green surface (Calvet-Mir and March 2019).

A number of studies highlight the risk of temporary uses taking opportunities away from permanent development (Blumner 2006; Reynolds 2011). A successful temporary solution can become an asset that could be a subject of community resistance when it reaches the end of its development cycle, and consequently, deter future development of the site. When users become attached to a meanwhile site, conflicts of interest may arise (Blumner 2006). This has the potential to discourage landowners from allowing interim uses on their sites. Another risk of temporary use is the potential of it blocking permanent development (Bishop and Williams 2012). Even though research on temporary use hasn't indicated it in discouraging permanent development, it still appears to be affecting interim use (Henneberry 2017). Many landowners may prefer to keep their land vacant rather than allowing its temporary use (Reynolds 2011). This ambiguous nature of temporary development makes it difficult to accept interim use as part of the cycle of land development.

Similarly, research provides a clear understanding of some of the challenges of temporary commercial uses on vacant lands. A study of the impact of food trucks on a single-family home neighborhood showed signs of increased livability as more visitors were attracted to the area (Freybote et al. 2017). The study also revealed that homeowners saw it as a disadvantage due to the resulting trash accumulation, decrease in parking availability, and increased noise and traffic. According to the study, this could suggest that food trucks may have a positive effect on the rental market. In fact, a number of food truck sites were developed into commercial and residential rental units. Other studies surveying landowners and developers reveal a general timidness in working with municipalities to temporarily develop vacant lands. Their main concern is the fear that such temporary intervention may "downmarket" the value of their properties (Martin et al. 2019).

4.2.4. Assessment of temporary urban regeneration

Research falls short in investigating the development and assessment processes of temporary solutions (Henneberry 2017). Analyzing the process of property development in light of interim use is useful in identifying key factors. A dominant focus in research highlights factors that include economic, cultural, and regulatory factors. These factors are generally influenced by the prevailing local perception of temporariness that dictates the variables and risks associated with the development process (Bishop and Williams 2012). A critical exploration of these factors identifies a relationship between physical spatial needs and behavioral and societal needs (Moore-Cherry and Mccarthy 2016). Most literature neglect to comprehensively highlight that the fulfillment of these needs differs from one site to another. This explains why the assessment of temporary urban environments does not follow a typical process and therefore constitutes its own efforts of inquiry.

The cycle of development, on the other hand, receives little attention. On the issue of time, for example, generic claims are made when referring to site-specific factors such as context and scale (Tonkiss 2013). This shows the limitation of temporary urbanism research and highlights a need to explore the role of temporary use in achieving regeneration objectives. One way to address this issue is by studying the connections between temporary use and land vacancies (See Chapter2). This can be achieved through a model that integrates key factors of the development cycle into an analytical framework to create a decision-making device that takes context, duration, and scale into account. Such an approach has been proposed to address the complexities associated with temporary development and the challenges of vacant lands (See Chapter 3). Understanding the role of temporary development in this light helps justify the rationale of establishing interim uses within a circular development process.

The case study presented in this paper aims to evaluate the environmental impact of a temporary urban regeneration intervention established using decommissioned shipping containers that are repurposed to serve as structural units in an urban setting. The research utilizes a MSLCA model to address the cumulative impact of two joined systems (See Chapter 3). This research addresses the life cycles of two systems, one of vacant land and the other of shipping containers in the city of Riyadh. The goal is to provide a decision-making tool that fits into a circular model of consecutive reuse cycles.

4.3. Methodology

Life cycle assessment (LCA) is a tool developed to evaluate individual products and systems. LCA is frequently used to help make decisions on the environmental impact of different options at different stages of a product's cycle (International Standard Organization 1997). Life cycle assessments can expand to evaluate complex systems such as building products and urban systems (Lotteau et al. 2015). The goal of this research is to assess the impacts of temporary urban interventions on vacant lands using shipping containers as a tool. The dual-system intervention assessed and discussed in this paper is a convergence of two separate systems with their own processes and flows. This introduces an opportunity for the application of the MSLCA framework for assessing the interactions between the two systems as introduced in Chapter 3. The methodology utilizes a model for assessment that merges and integrates the two systems to highlight their mutual impacts on the overall scope (Figure 36). Once mapped and defined accordingly, the model can be used as a decision support tool for comparison of appropriate development scenarios of short-term use.

The objective of a MSLCA framework is to help identify the overall combined consequences of decisions adopted in both systems. The model consists of two main processes (Figure 37). The first is an implementation process that identifies the main systems, the objective of the assessment, the interventions that join the systems, and the parameters that guide the assessment. The second is an evaluation process that lays out the steps for the assessment through identifying indicators, executing the assessment, communicating the results, and providing appropriate contributions to make decisions regarding the systems. The model also addresses the collection of data and quantification procedures for the inputs and outputs of the product system. Input and output data are modeled based on specific information about the system and its life cycle processes. To minimize uncertainties in the process data, the assessment gathers site specific data from local sources and reference data from relevant research.

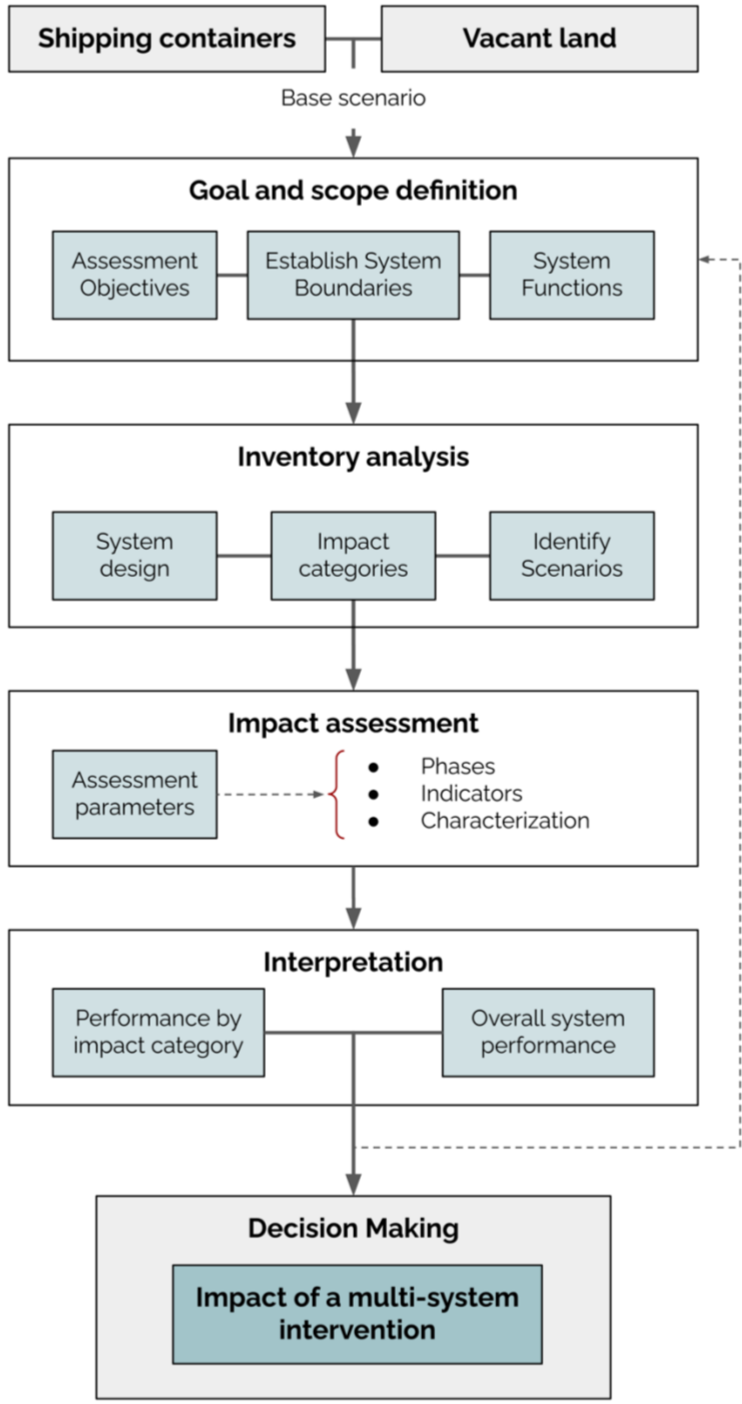

Figure 36. Overview of the Multi-System Life Cycle Assessment (MSLCA) steps

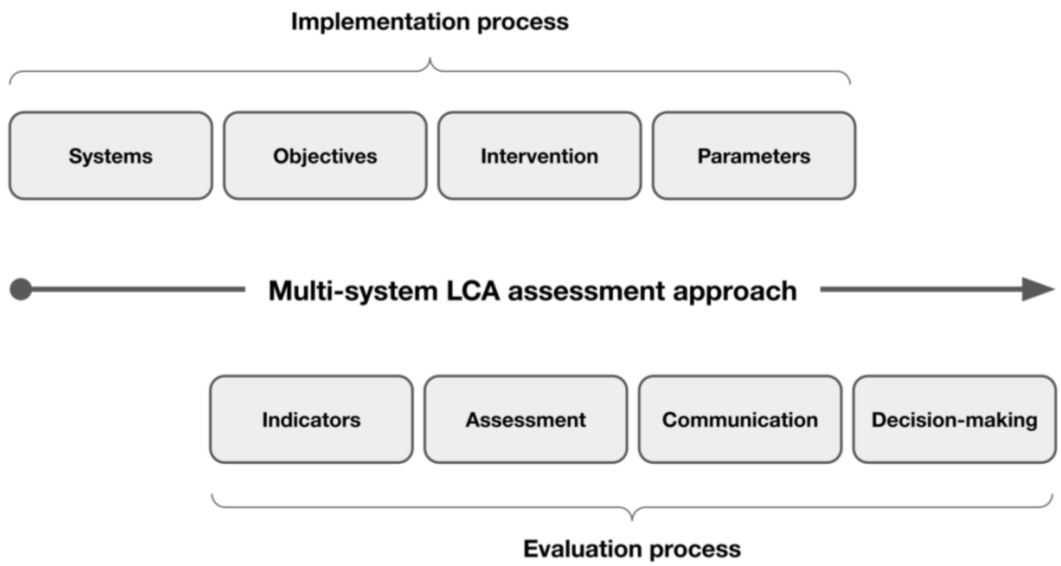

Figure 37. Processes and Elements of the MSLCA approach

4.3.1. Goal and scope definition

Assessment of Objectives

The goal of the here developed multi-system life cycle assessment is to determine the urban regeneration capacities of vacant lands and decommissioned shipping containers for urban regeneration and to analyze the environmental impact of both systems during their otherwise idle stages. The objective of this assessment is to highlight hotspots in both systems during that stage by comparing different utilization case studies. These hotspots are areas of high or low impact that could guide decision as the assessment realizes their significance. The scope of the here evaluates scenarios considers the production of a proposed temporary urban regeneration intervention option in reference to comparative and life cycle options for the assessed systems. The model used for the assessment prescribes a number of system pathways. These pathways describe scenarios for both systems that provide utilization courses to the observed problem. The model explores aspects of the problem as it relates to the investigated urban vacancy and shipping container storage problem.

System functions

The multi-system setup in this case study serves two main functions. The first is an urban regeneration function accomplished through a temporary appropriation of vacant lands. The second is a resource management function carried out through the repurposing of decommissioned shipping containers. The objective is to highlight potential opportunities where the two components act together to create a system that provides a combined solution to the observed problems. Decisions on appropriate opportunities are guided by extracted interest areas in the literature. This includes defining parameters for cross-system integration based on applicable categories.

System Integration Boundaries

The system integration boundaries define the scope of the established parameters for the combined assessment, which include its related processes and inputs and outputs for each subsystem. These boundaries are designed to meet each scenario's function in the joint context. In this case study, the system boundaries include the production activities for the scope of the intervention of all assessed scenarios, including their related energy and material inputs. In the case at hand, which only investigates the environmental impacts of interventions. This pertains to activities that contribute directly to environmental metrics by one or both systems. These include transportation as well as site work and construction activities within the established contextual and functional boundaries.

4.3.2. Inventory Analysis

System design

The first stage of the *Inventory Analysis* step is the system design stage which pertains to extracting use case scenarios that are applicable for either systems. The aim is to highlight opportunities for value creation from the idle stage in each system. The system design recognizes four scenarios that cover potential utilization pathways. In this case study, the investigated scenarios cover potential pathways starting from a "status quo" of a no intervention scenario to an "end-of-life" scenario for both systems. The system design addresses all the related processes associated with the systems and assessed scenarios. This step also establishes the categories of impact selected for the assessment.

Life cycle inventory

The life cycle inventory design stage needs to address the life cycle processes and their related data necessary to define the system functions. This includes data for the established assessed scenarios, which are populated based on the use case options. The use case options are the model's approach to reflect the processes related to both systems (Figure 38).

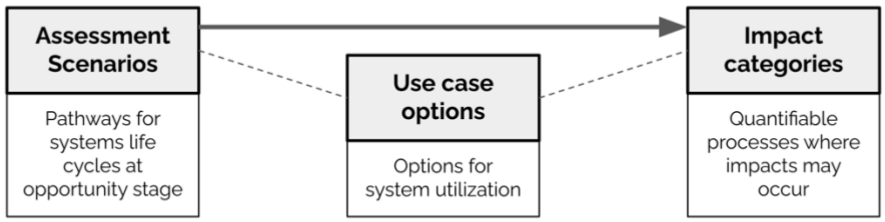

Figure 38. Main components of the assessment's life cycle inventory

4.3.3. Impact Assessment

At this stage, the *Impact Assessment* step establishes procedures for collecting source data, ensuring the completeness of inventories, and tracking related metrics into and out of the system. This case study assessment uses the software OpenLCA 1.10.3 with the Product Environmental Footprint (PEF) database, which includes characterization and normalization for the impacts performed. Depending on the process being modeled, case-specific data (primary data) and generic data (secondary data) were used. Primary data from the site were used to estimate case-specific impacts. This includes data on transportation distances and material sourcing. Secondary data on production and construction were collected from different literature and commercial databases. Data on retrofitting shipping containers are mainly based on reference studies. Research on this issue lacks a complete inventory analysis from raw materials to construction and use.

4.3.4. Interpretation

The *Interoperation step* for multi-system assessments consists of two main components. The first pertains to calculating impacts per category. These categories were established in the goal and scope phase and investigated processes from one or both systems that influence the overall system of intervention. In the case of a temporary urban intervention that utilizes shipping containers on vacant lands, impacts were categorized into three process streams. These streams are the materials and components transportation processes throughout the system, the material and site work processes, and lastly the actual construction processes. The second component of the *Interpretation step* pertains to adding up the impacts to determine the overall system performance. This allows for comparing the different impacts of assessment scenarios and their use case options These results are meant to highlight differences in impacts between utilization pathways to help guide decision-making for both systems during their unproductive stages.

4.4. Analysis

This assessment is primarily interested in the prevailing impact of urban regeneration in the context of temporary land appropriation using repurposed shipping containers. Therefore, the analysis mainly focuses on one design solution with the two system streams. The goal is to assess a use case option that provides the minimum requirements for most literature documented temporary uses. This allows for flexibility in adopting this use case option for broader scenarios and design options with a clear understanding of key areas of impact.

4.4.1. Base scenario

The scenario investigated in this case study is the proposal for the creation of a community space for social and recreational uses utilizing shipping containers on a vacant land in Riyadh. The space includes: (i) open public space for recreation. (ii) covered space for pop-up events. The vacant land used in this study is a 1,000 m^2 (0.25 acres) within a residential subdivision that is privately owned and located at the center of a partly developed, low density subdivision. This is an ideal lot size for an intervention of this kind as it within the typical size of residential lots in the area. The intervention consists of a $60m^2$ built area with 12 car parking spaces. The design specifies the use of paved walkways and gathering areas, and pervious surfaces for landscaping. The less than a year intervention requires moderate alterations to the land and shipping containers to be used on site (Figure 39).

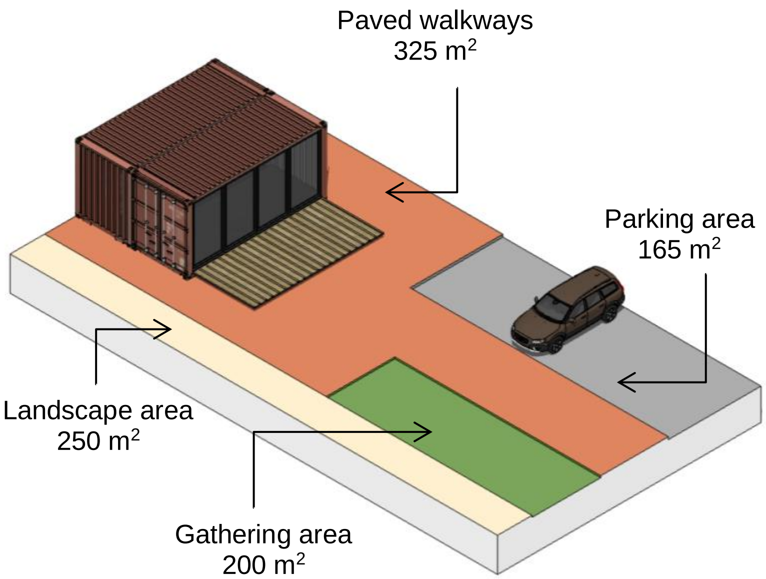

Figure 39. Section of system components of the proposed system (not actual design)

4.4.2. Assessment scenarios

These scenarios are categorized by case study options. This includes an urban intervention scenario that is temporarily joining the two systems to create the proposed regeneration system. In the comparative regeneration scenarios, the assessment is only concerned with transportation, landscape materials, and structure construction impacts. This assumes that impacts related to other processes are equal between comparable case study options. At this stage, the objective here is to provide relative results for the case study options rather than a comprehensive performance assessment.

The basic assessment scenarios that can be observed in this use case include (Table 4.4.1):

- **Status quo scenario:** In this scenario, the assessment model highlights the current "idle" stage of both systems. The scenario considers the status quo stage of the systems, and thus could acts as a baseline. For the shipping container, this stage pertains to storing the decommissioned containers at one of the area's storage yards. For the land, this stage pertains to a state of vacancy with no prospect for development. This scenario does not present any relevant environmental impacts that could affect urban regeneration aspirations. Since we assume in this case that we want to pursue an intervention, this scenario will, in the end, not be considered for temporary urban regeneration decision-making.

- **Traditional scenario:** This scenario considers a conventional pathway for both systems. In scenario number two, the assessment considers options for returning the shipping container from the inland port to one of the two major sea ports in the country. The transportation options that are available in the area of study consist of a train or flatbed lorry. The case study option for the land considers a community use of the land for a single pop-up event. This scenario is established to present an alternative bypassing the use of shipping containers as a structure within a temporary urban regeneration project meeting the same needs.
- **Proposed intervention scenario:** This scenario concerns the environmental life cycle impacts of the production of the proposed urban intervention system. This scenario merges the two systems together to showcase their urban regeneration potential. The analysis considers the impacts associated with occupying the land by evaluating commonly used landscape materials that are appropriate for temporary use. The analysis also includes an evaluation of impacts associated with processes used for repurposing shipping containers into structural units. Contextualization is applied to typical local construction processes. Generic data are used for representative impact values of material categories.
- **End-of-life scenarios:** Scenario four, on the other hand, considers "end-of-life" to the idle stage scenario. For the shipping container, this stage pertains to recycling processes that include the dismantling of material and melting of steel. For the land, this stage pertains to developing it into a residential unit per area ordinance. This scenario produces no measurable urban regeneration value. Consequently, as this scenario will not differ in impact from baseline scenario, it will not be considered for the scope of temporary urban regeneration decision-making.

Table 4.4.1 proposed assessment scenarios of both systems

	Scenario 1 (Status quo)	**Scenario 2 (Traditional)**	**Scenario 3 (Proposed intervention)**	**Scenario 4 (EOL)**
Shipping container	Idle Case study A-1: No intervention	Transport to port • Case study B-1: Transport via lorry • Case study B-2: Transport via train	Proposed temporary intervention • Case study C-1:	Dismantled & melted • Case study D-1: Recycled at processing depot

Vacant land	Idle Case study A-2: No intervention	Alternative intermittent use • Case study B-3: Single pop-up event	Low impact materials used for the container and construction of the site	Developed Case study D-2: Conventional development option

4.4.3. Functional unit

The functional unit (FU) describes a reference unit of the product system to ensure that results are accurately compared equally to a "function" rather than a product (Weidema et al. 2004). In a complex multi-system LCA, the functional units can be a unit of magnitude, duration, as well as, a qualitative description of the product system. The proposed functional unit represents both systems. For this assessment, it is a land area of 250 m^2 on top of which is one twenty-foot equivalent unit (1 TEU), which is the volume of one 20ft shipping container.

4.4.4. Life cycle inventory

The life cycle inventory considers the impact categories intended for the assessment based on the scenarios and related use case options. The impact categories addressed in this assessment are transportation, site production, and structure construction (Figure 40).

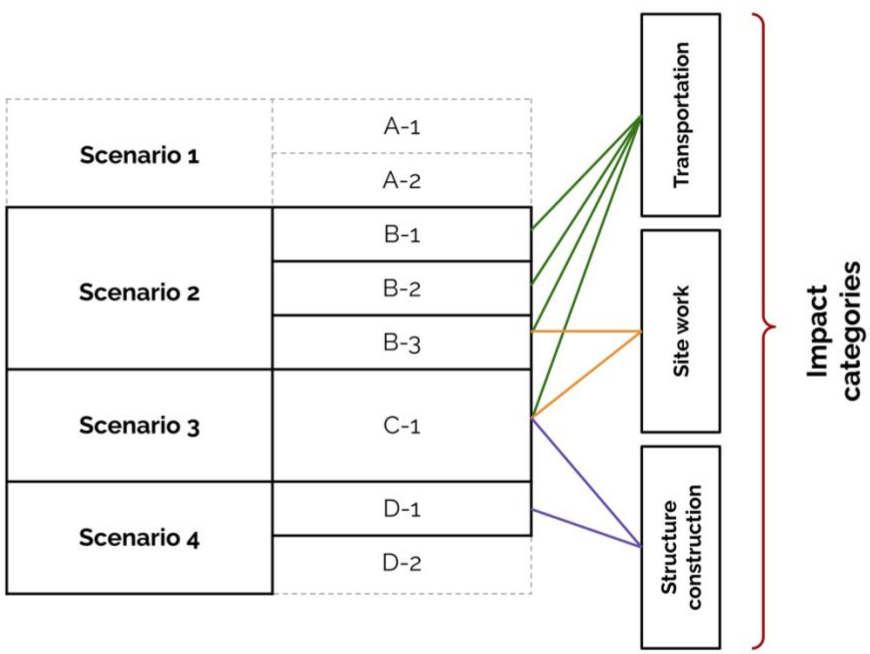

Figure 40. Considered impact categories for the assessed scenarios

Transportation. The assessment takes into account the environmental impact of the system components' movement throughout the system. This includes the transportation of shipping containers and other materials categorized by case options. Reference data were used to categorize impacts by mode of transportation (Table 4.4.2). System-specific data were used to determine the volume and distance traveled of system components.

Table 4.4.2 Inventory data for transportation processes

Scenario	Case study	Description	Mode	Distance	Ref. data
#2	B-1	Transport container to port	Class 8, over 16t diesel flatbed lorry	945 km	Fuel: 1.8-1.9 L/100km. Energy: 99 MJ/100km Emission: 7.7kg CO_2e / 100km
	B-2	Transport container to port	Diesel freight train	475 km	Fuel: 0.34-0.36 L/100km. Energy: 19 MJ/100km Emission: 1.5 kg CO_2e / 100km
	B-3	Transport materials to site	Class 4, 7t diesel truck	40 km	Fuel: 4.25 L/100km
#3	C-1	Aggregate	Class 6, 10t diesel truck	85 km	Fuel: 2.97 L/100km
		Hot mixed asphalt	Class 6, 10t diesel truck	70 km	Fuel: 2.97 L/100km
		Turfgrass (sod)	Class 7, 16t diesel truck	110 km	Fuel: 2.55 L/100km
		Transport container to site	Class 8, over 16t diesel flatbed lorry	40 km	Fuel: 1.8-1.9 L/100km. Energy: 99 MJ/100km Emission: 7.7kg CO_2e / 100km

Site work and construction. The assessment covers the site work and construction processes of a variety of intervention options as it relates to the vacant land and shipping container. The assessment considers materials and energy flows of the production and construction processes for each system component (Table 4.4.3). Data for the scenario options are inventoried in reference to the functional unit and specific parameters of the site. The data for the retrofitted structure of the shipping container are documented and linked to the processes necessary to produce the structure. Reference data for material and energy required are reported for the functional unit. Reference research is considered for data on cutting, welding, and reinforcing processes required for container construction.

Table 4.4.3 Inventory data for production and construction processes

Scenario	Case study	Material	Description	Ref. data
#2	B-3	Canopy structure	12 m2 soft fabric tent	Total weight: 20.85 kg
		Compact aggregate (gravel)	165 m2 (parking area)	1,700 kg/m3 density
		Turfgrass (sod)	250 m2 (landscape area)	21.45 kg/m2
		Event furniture	6 aluminum chairs 2 wooden benches 2 aluminum tables	Total weight: 200 kg
#3	C-1	Foundation blocks	16 units	40 x 40 x 40 cm units weighing 40 kg/ea with strength of 5,000 psi.
		Compact aggregate (gravel)	250 m2 (landscape area)	1,700 kg/m3 density
		Turfgrass (sod)	200 m2 (gathering area)	21.45 kg/m2
		Hot mixed asphalt	165 m2 (parking area)	2,300 kg/m3 density

4.5. Results

The results of the environmental impacts for both systems were calculated based on the established scenarios. These scenarios account for the use case options related to potential events at the idle stage of both systems. One of the assessed scenarios integrates the two systems together for a temporary urban intervention to help guide urban regeneration decisions. The goal of comparing these scenarios was to highlight the potential advantages of temporary appropriation of vacant lands, as well as, determine the value of reuse vs. recycling of shipping containers.

The results focus on processes rather than phases to highlight the impacts of use case options on the systems at certain stages in their life cycles (Table 4.5.1). The assessment addresses impact categories of transportation, site work, and structure construction processes. The results highlight dominant Impact indicators such as acidification potential (AP), climate change (CC), ozone depletion (OD), resource use, and water use. The results also discuss contextual implications relating to material sourcing.

Table 4.5.1 Normalized results of assessed scenarios categorized by impact category

	Impact category:	Acidification	Climate change	Ozone depletion	Resource use, fossils	Water use
	Unit:	mol	kg	kg	MJ	m 3
Transportation	B-1 (Container via lorry)	0.0029	0.0019	1.50E-09	0.0030	0.0000037
	B-2 (Container via train)	0.0032	0.0023	1.26E-09	0.0036	9.87E-07
	B-3 (Furniture)	5.13E-05	4.05E-05	2.17E-11	6.41E-05	1.59E-06
	B-3 (Gravel)	0.00059	0.00042	2.28E-10	0.00067	1.68E-05
	B-3 (Sod)	0.0030	0.0022	1.19E-09	0.0035	8.75E-05
	C-1 (Container)	0.00027	0.00019	1.06E-10	0.00031	0.0000078

	C-1 (Foundation Blocks)	0.00018	0.00014	7.78E-11	0.00022	5.72E-06
	C-1 (HMA)	0.0065	0.0047	2.55E-09	0.0074	0.000188
Site work	B-3 & C-1 (Gravel)	0.0016	0.0019	7.51E-08	0.0033	0.00015
	B-3 & C-1 (Sod)	0.0036	0.0055	1.48E-05	0.0097	0.31
	C-1 (HMA)	0.067	0.14	5.44E-06	0.18	0.011
	C-1 (Foundation Blocks)	0.017	0.039	2.042E-06	0.053	0.0039
Structure	C-1 (Container retrofit)	0.0057	0.013	1.71E-06	0.028	0.0012
	D-1 (Container recycling)	0.11	0.27	3.42E-05	0.56	0.025

The assessment mainly looks at the impact of the proposed temporary urban intervention on vacant lands using shipping containers in comparison to other options for both systems. In the case of the proposed intervention scenario, the results show that the repurposing of the shipping container and the site work processes of the site with its related materials share the majority of the calculated impacts. In fact, 88.6% of the climate change impacts and 81.7% of the acidification potential impacts are represented by the site work processes. This includes the production and construction of materials such as asphalt, gravel, turfgrass, and others. In fact, the climate change impacts of production processes contribute to over 1,572 tons of CO_2, 57.2% of which is represented by the production of hot mixed asphalt making it by far the highest for the component making the intervention (Figure 41).

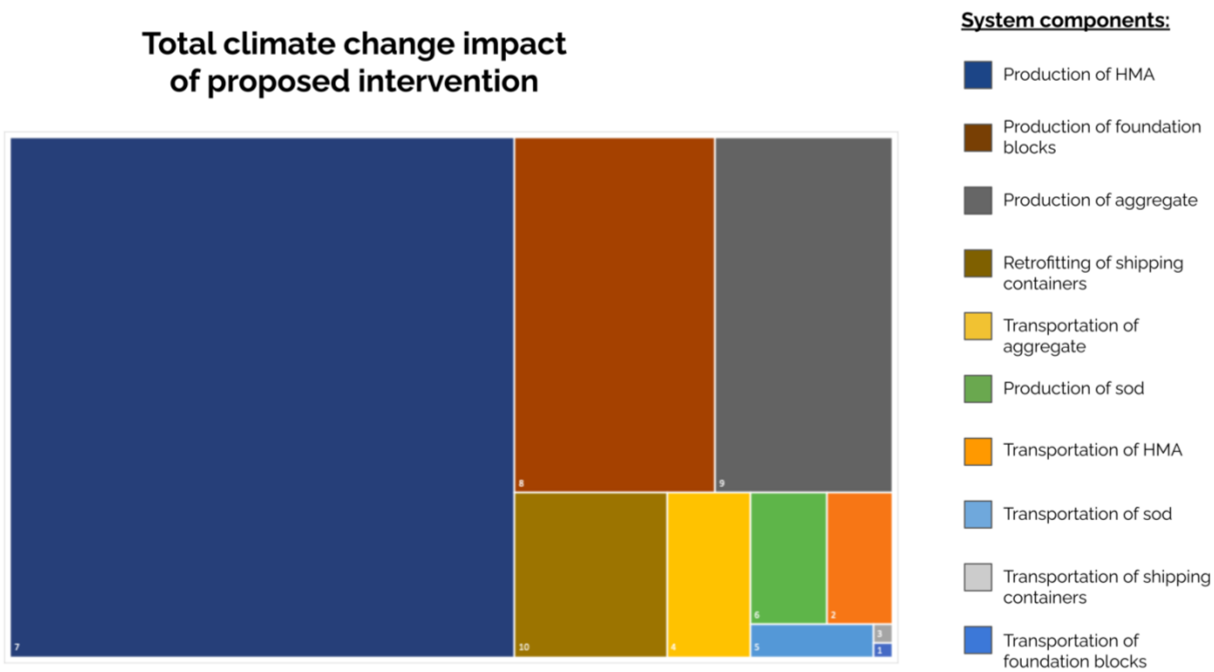

Figure 41. Climate change impact of the proposed temporary intervention by process and system component per functional unit

Looking at the separate processes that make up the overall proposed temporary intervention, the result shows the impact of material production as the most dominant (Figure 42). Given the context of the intervention, most materials selected are conventionally used in the region and produced within the city's boundaries. On the other hand, for the container system, the processes of retrofitting the container into a usable structure are significantly less dominant in their effects on the system. The results highlight the fact that the use of shipping containers in this manner contributes anywhere between 1% - 5% of the overall impacts. In fact, repurposing a shipping container produces little over 106 kg of CO_2. The assessment also shows the comparable effects between the site work and container structure processes as well as transportation impacts relative to the distances and modes of transportation of these system components as they move throughout the system.

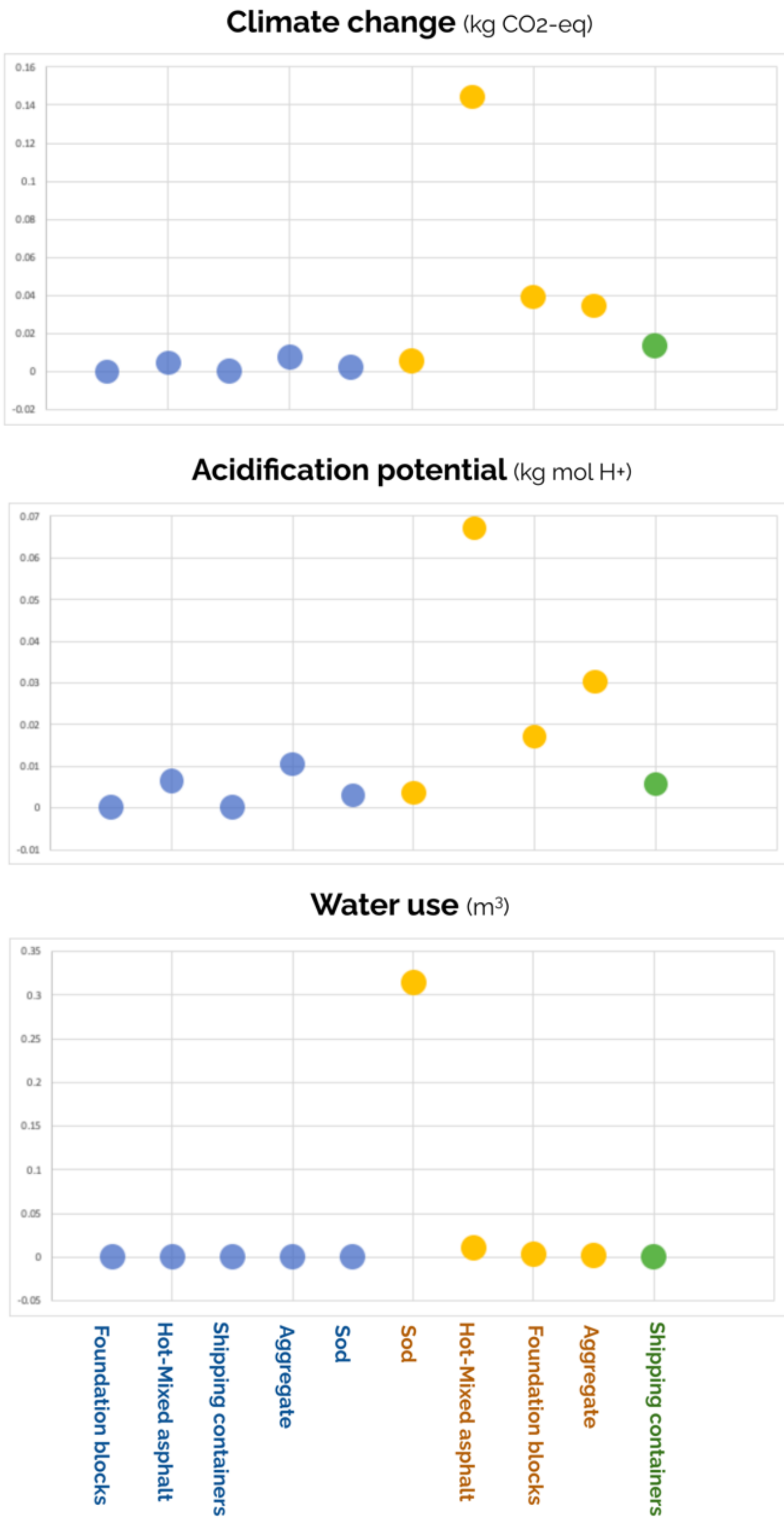

Figure 42. Impact of the proposed temporary intervention categorized by system components across selected indicators

4.5.1. Transportation

This category addresses the impacts of system components' movement across the assessed scenarios of use case options. This includes the scenario option of transporting the shipping container to ports and site using transportation options of a diesel freight train and 16-ton diesel flatbed lorry. In terms of impact, the results show that transporting containers the same distance via train outputs significantly less environmental impacts compared to lorry transportation across most indicators. In fact, the results show that it produces 70.5% less climate change impact and uses 79.1% - 70.6% less water and resources respectably. In the case of returning decommissioned shipping containers to ports, the impacts savings of train transportation are amplified over lorry transportation due to the significantly longer distance a lorry needs to travel to reach the port (Figure 43).

In terms of the proposed temporary urban intervention, transportation impacts are mainly linked to the volume, distance, and mode by which materials are transported. Additionally, the context of material sourcing plays a significant role in their impacts. The impact of the urban intervention scenarios where the heaviest materials and furthest from the site are the ones with the most implications per functional unit. The results show that total weight is the determining factor of overall environmental impact. This is clear as it is reflected in the impact profiles of the proposed intervention components (Figure 44). Foundation blocks used as footing to lift the containers off the ground are the heaviest by functional unit. Yet, they contribute a fraction of the overall impact due to their small size, quantity, and used mode of transportation. Similarly, the transportation of a functional unit of turfgrass represents a high impact due to the distance between the supplier and the site (110 km), however, such impact pales in comparison to heavier components in the overall impact. On the other hand, other components such as aggregate and asphalt show the opposite disparity between their impact per functional unit and overall impact.

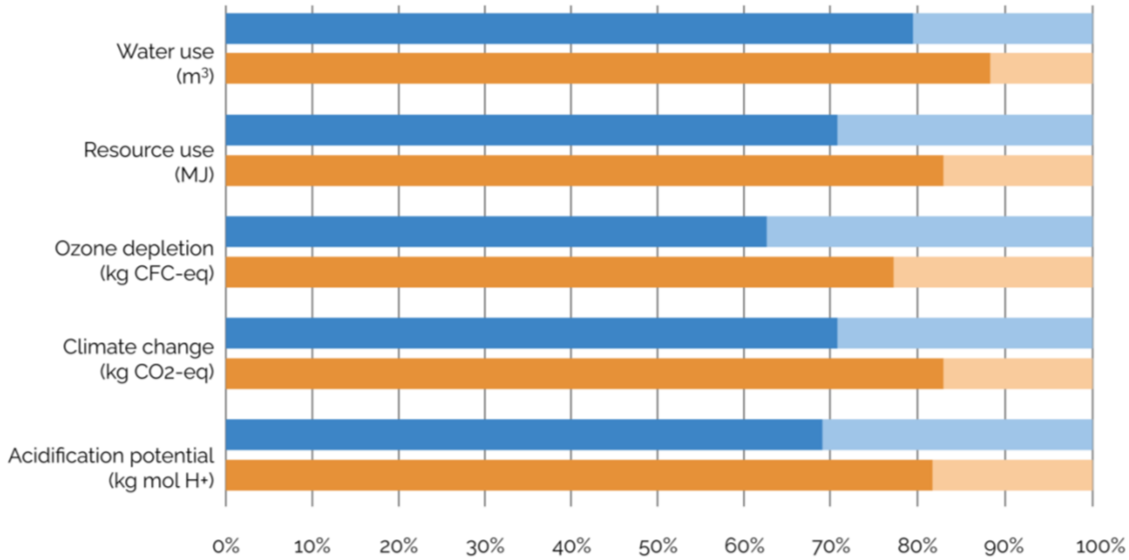

Figure 43. Transportation impacts of moving 1 TEU shipping container using available transportation options; flatbed lorry (dark color) and freight train (light color) for a distance of 1 km (blue) and total distance to port (orange) across selected indicators

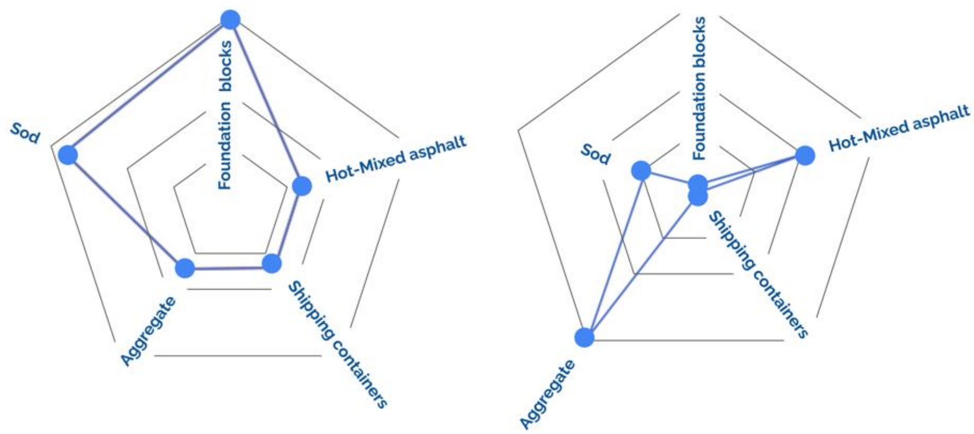

Figure 44. Transportation impact profile of proposed urban interventions components per functional unit (left), and overall (right)

The assessment results help compare scenarios of temporary land appropriation to enable decision-making with regard to the two systems. The model provides an opportunity, through use case options, to highlight hotspots by separate processes. This is especially useful with shared components across the assessed use case options. For example, although the climate change impacts of transporting turfgrass are relatively equal between scenarios B-3 and C-1, the disparities of impacts of transporting gravel are much higher (Figure 45). The quantities transported are the main factor in this particular process, therefore, such results highlight a potential hotspot that could guide valuable decisions.

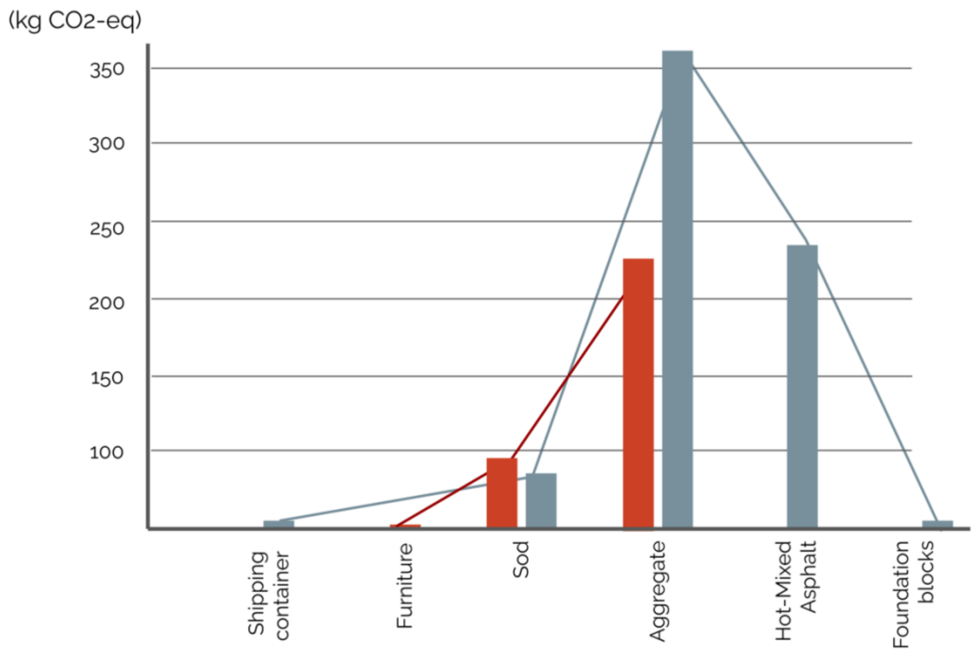

Figure 45. Climate change impacts of transporting system components of temporary urban intervention use case options, B-3 (red), C-1 (gray)

4.5.2. Site work and construction

This category addresses the impacts of use case production. Mainly site work processes of the urban intervention and its related material production processes. The commonly used landscaping materials are selected for the intervention and assessed based on predetermined quantities per the functional unit. The results present the impacts of both systems to highlight their contribution to the interventions. The construction of a structure out of a shipping container, although seemingly high per functional unit, produces a fraction of the total impact in the proposed intervention scenario (Figure 46). The energy needed to repurpose one TEU of a shipping container into a usable structure is about 1,800 MJ. At this rate, the total energy needed to transport materials to the site is equivalent to the energy needed for the transformation of shipping containers into a usable structure. Such impact is a result of the degree of alteration to the original structure of the shipping container. The proposed intervention addresses minimal modifications that include a 3 m^2 opening with a canopy for service. This is the goal of the intervention which is to provide a contained lockable space for users to utilize. The addition of systems and appliances to the container structure can significantly increase the impact of repurposing containers. On the other hand, the majority of impacts result from landscaping materials used to create the site.

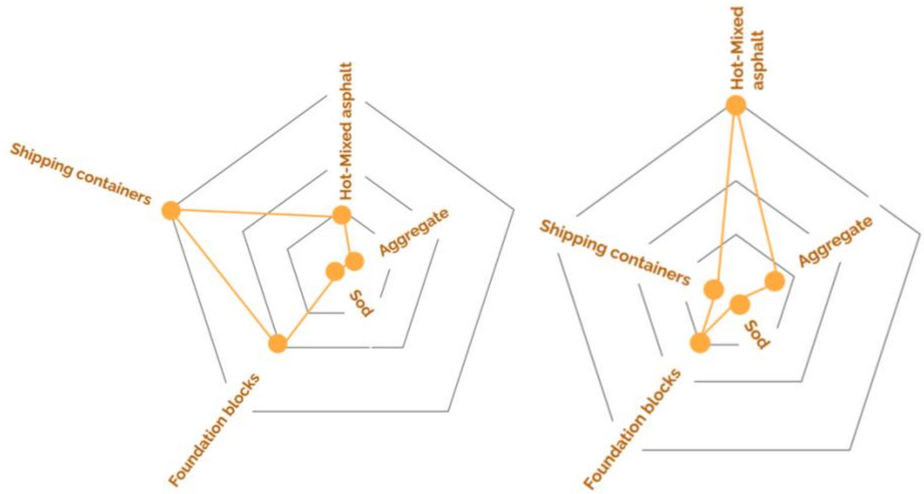

Figure 46. Production and construction impacts profile of proposed urban interventions components per functional unit (left), and overall (right)

A comparison of the impacts of urban intervention scenarios including the processes of site work and construction highlights the disparities of impacts between site appropriation options. These differences are mainly linked to system components and the duration of the intervention. Mainly, the material used and the projected life span of the scenarios dictate the environmental effects. In scenario (B-3), for a single event, the use of easily deployed components is more appropriate. This is reflected in the results as the impact of widely available materials that require minimal assembly and construction shows significant environmental savings (Figure 47). In fact, the overall impact of the proposed single event scenario (B-3) only counts for 5.9% of resource use impact, and 4% of climate change impact of the proposed scenario (C-1) involving the use of repurposed shipping containers. However, if the duration of such intervention were to be extended to a prolonged period of time, the replacement effect could close the impact gap between the two scenarios.

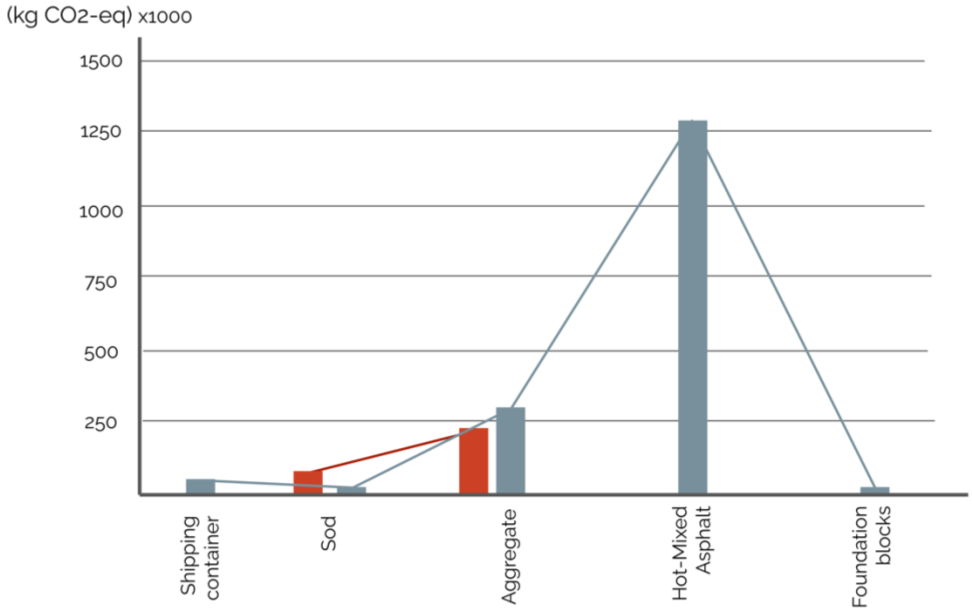

Figure 47. Climate change impacts of producing system components of temporary urban intervention use case options, B-3 (red), C-1 (gray)

4.6. Discussion

The purpose of this assessment was to demonstrate and evaluate the MSLCA model for a multi-system life cycle assessment. The results revealed a several points regarding the suitability of such an approach. A central contribution is the validation of the model as a pathway for merging two systems to create an interim system at the idle stage of each subsystem. Given the assessed scenarios, evaluating the proposed intervention in tandem with other case study options provides an outlook for potential hotspots and improvements. These hotspots won't typically be visible within each system's lifecycle, however when coupled with another system, new processes are created. Such processes account for new flows, boundaries, and above all, contexts. For a temporary urban regeneration system context is key in understanding restrictions to the scope. Providing the urban context, the scope of the assessment can be narrowed or broadened based on limitations that the context imposes. Once limitations are identified and established the model can be applied to a wide range of settings. Moreover, the model fits the transitory state of a temporary system. This allows for a focus assessment of interventions without the need for a cradle-to-grave assessment. The definition of boundaries can be set based on processes emerging from the multi-system integration. This includes related input and output streams from all processes to enable the transferability of outcomes across systems.

4.6.1. Implications of shipping containers use

The use of repurposed shipping containers for temporary urban interventions presents opportunities seldom explored. In this case, the assessment has been exclusively conducted to include transportation and construction processes (Figure 48). These processes were selected to fit the specific intervention and to address the issue of inland ports accumulating decommissioned containers. The implication of evaluating shipping container use in this light highlighted issues beyond environmental impacts. In many cases returning containers back in circulation is not an option. The logistics, ownership, and condition of the container are only a few factors that prevent container reuse. Therefore, repurposing options create new avenues of utilization that feed into, in this case, an urban system in need of a “meanwhile” structure. Such an approach has the potential to replace construction materials used to establish needed urban intervention. Additionally, it can extend the useful life of containers or even save them from early dismantling and potentially avoid the production of new containers. At a minimum, it can replace construction materials used in the here shown regeneration use case.

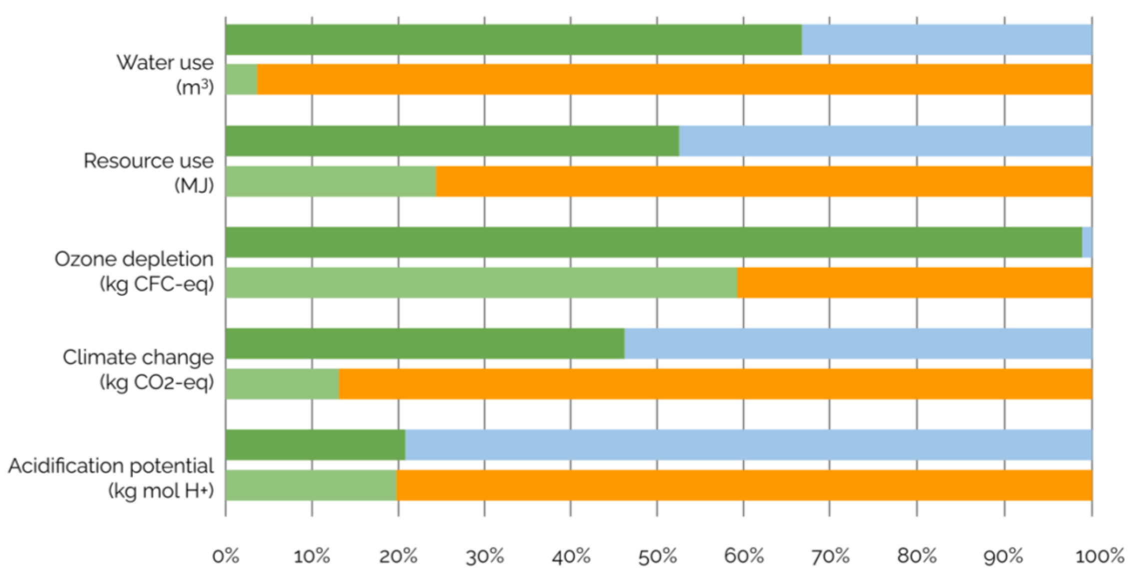

Figure 48. The overall impacts of repurposing shipping containers into structures for use in the proposed intervention (green) as is related to transportation impacts (blue) and site production (orange)

4.6.2. Implications of repurpose vs. recycle

The repurposing of shipping containers generally refers to the reprocessing of their structure for alternative use at any given stage of their lifecycle. This could encourage a closed-loop system where energy and materials are preserved within the system. In fact, if the repurposed product serves a higher function or provides better utility, the repurposing process could be considered a product upcycling. Recycling, on the other hand, mainly implicates material recovery at the end-of-life stage. Reclaimed recycled materials can be reused which could help lower the demand for new material production hence mitigate resource depletion. However, new materials produced through recycling are often degraded. Such loss of material and energy labels recycling as an open-loop system and is often considered as downcycling. Consequently, an implication of repurposing shipping containers is the opportunity of capturing system outputs back as inputs. Minimizing material waste is one key advantage of repurposing over recycling. Depending on the degree of alteration; a repurposed product can potentially be restored to its original state and returned back to the system. Therefore, repurposing can occur at any stage of the product's system whereas recycling generally occurs at the end-of-life stage. Another implication of repurposing containers is energy savings. The results show significant energy savings across all indicators when comparing repurposing to recycling options. The process of dismantling and processing a decommissioned shipping container is extensive and requires significant energy input to extract materials and recover them to their usable raw state. The results show up to 95.25% savings in energy for repurposing one TEU container over recycling (Figure 49). In fact, repurposing produces 106 kg of CO_2, consumes 1,829 MJ of fossil energy, and 14.7 m^3 of water; as opposed to 2,130 kg of CO_2, 36,619 MJ of energy, and 296 m^3 of water if recycled. Such savings depends on the use case and the extent of container conversion, nonetheless, most research indicates similar results (Islam et al. 2016). Furthermore, environmental benefits of shipping container reused can be maximized by simplifying the conversion processes as in the case of this study.

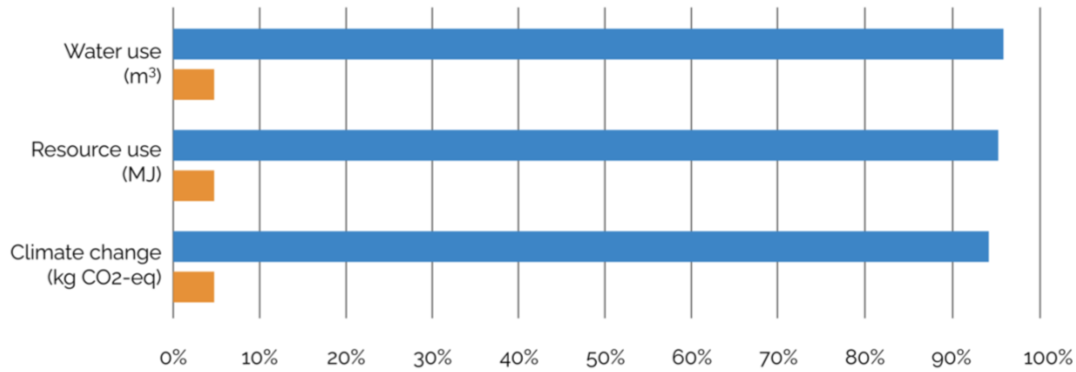

Figure 49. The impact of repurposing 1 TEU of shipping container into usable structure for the proposed intervention (orange) as it relates to recycling it for raw materials (blue)

4.6.3. Implications of material use

The selection of materials used in the use case options, specifically the temporary regeneration scenarios, can significantly alter the overall impact of an option. Similarly, material sourcing options influence the impact as transportation processes are a major part of the systems (Figure 50). In order to make decisions, addressing the overall impact is often more important than considering impacts per a functional unit. This is highlighted in the transportation impact of aggregates and production impacts of asphalt. Both materials have significantly higher overall impact compared to their functional unit impacts. This is the main goal of this model which is to guide actionable decisions on intervention parameters. It is also flexible on which hotspots are more important for each study. This depends on the objective of the assessment and scope of the study in which indicators are selected according to damage-based, prevention-based, or single-issue indicators.

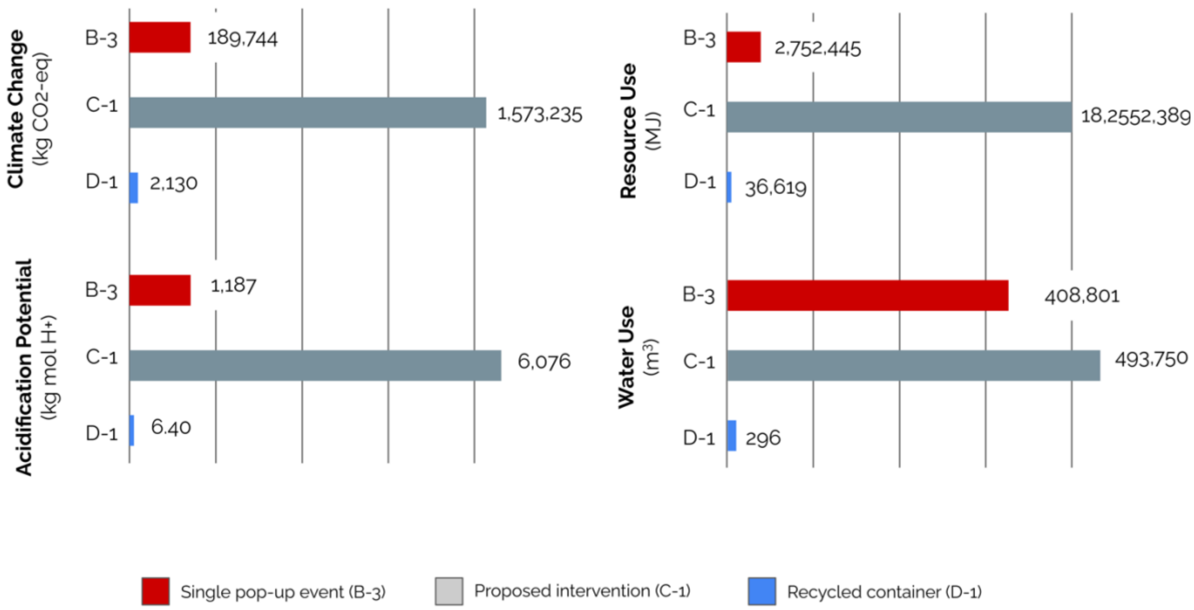

Figure 50. Impacts of assessed scenarios B-3 (red), C-1 (gray), & D-1 (blue) as they relate to each other

4.6.4. Implications of Multi-System LCA

The application of the MSLCA model enables the assessment of complex multifunctional systems. The model is effective in assessing selected processes that influence both systems. Placing emphasis on particular dimensions in multi-system assessments highlights impacts that are often unaccounted for in single system assessments. One main challenge is the availability of case specific data connecting the two systems in a comparable way. A core issue at the data collection stage is the inclusion of more process representative data. However, both systems provide incomparable scenarios due to the nature of their processes. This is where the need for a base scenario to establish a degree of fixed parameters to diminish or control variabilities between integrated systems. In an urban system, these variabilities are mainly spatial, therefore, spatial differentiation is central in the base scenario to help set the parameters for site-specific activities. It can be argued that unlike typical LCA, background data are not as important in a multi-system assessment. In this case, the assessment focuses on foreground scenario-specific data. The reliability of such an approach needs to be further examined through subsequent studies with broader scope and larger scale. The lack of similar studies hinders a clear determination of the model's further applicability. However, at this prototyping stage the model can help make decisions for case-specific interventions that can produce value aside from the idle stage of assessed systems.

4.7. Conclusion

This paper demonstrates the application of a multi-system LCA model for a temporary urban intervention system. The model introduces an interdisciplinary approach to identifying sustainable opportunities. Through the merging of two separate systems, the model assesses creative interventions highlighting inefficiencies in both systems at their unproductive stages. The goal of the assessment is to evaluate the urban regeneration potential through the temporary appropriation of vacant land using shipping containers as building structures. In doing so, the paper reveals hidden synergies between the two systems while addressing the context and tools of the assessment method.

The results reveal the advantages of adaptive reuse and the value of transforming systems into new and creative functions. Within this paper, these advantages center around the environmental benefits of increasing materials' life cycle, reducing energy consumption, and redirecting waste. The selection of shipping containers as structural units stems from their availability, flexibility, and speed of transformation. Their structures also provide robust, durable, and modular units that increase the potential for alternative use. These advantages are amplified by the low barrier to vacant land appropriation.

Working with a location-dependent use case asserts a need for including site-specific data that address the activities and processes that take place. This is a challenge for such a multiscale issue, particularly when defining a functional unit. Here, the assessment happens at the micro scale but in an urban system most impacts occur beyond the system's boundaries. While this assessment considers two main regeneration scenarios, there is an opportunity to expand use case options with different design variant to fit specific context. Additionally, a broader application of the MSLCA model is appropriate to include additional parameters and metrics beyond environmental impacts. While still at an early stage, we consider an evaluation of economic and social aspects in future research is useful in supporting decisions at the macro level.

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Chapter 5 - Conclusions

This chapter provides a summary of the research and contributions of what has been investigated in this dissertation. It also offers a view of the observed limitations of the findings and possible avenues for future research. A central objective of the research is to develop the proposed Multi-System Life Cycle Assessment model (MSLCA) to help guide decisions on temporary urban regeneration. This is to contribute to best practices by addressing the performance of potential interventions through contextual analysis of regeneration opportunities.

5.1. Summary of contributions

Urban regeneration encapsulates the idea of changing the physical urban environment as a strategy to stimulate economic and social activities. It generally addresses the processes of rehabilitation to introduce new uses or provide needed services. Temporary urban interventions as a concept seek tangible developmental goals for a set period of time. In this context, temporary urban regeneration is considered as a tool to provide short-term spatial solutions. To understand the effects of such solutions, it is important to be aware of their impacts. This research studies temporary urban regeneration in this light to analyze the impacts of temporary urban interventions using the MSLCA model. The temporal aspect of the assessed intervention determines the contribution of each component in adding value to the overall system.

To better understand temporary urban regeneration, the first manuscript explored the literature to capture key parameters of the issue. The review of urban regeneration research was useful in determining areas of interest. Research presented considerable variation in responding to land vacancies through temporary regeneration. The findings covered a wide range of initiatives, contexts, and outcomes. A notable challenge that became apparent in research was the ability to determine the success of urban regeneration initiatives. It also became clear that research was concerned with discussing policy, sustainability, and stakeholders related issues. The review highlighted the state of the literature with regard to the addressed research problems. Consequently, the main contribution of the review was extracted performance indicators relevant to temporary use on vacant lands based on environmental, economic, social, and urban categories. These indicators were used to build parametric matrices to build the assessment model.

To utilize the findings of the literature review, the second manuscript provided a framework for Multi-System Life Cycle Assessment (MSLCA). The model proposed a life cycle assessment-based approach to evaluate two joint systems through temporary urban intervention and address the research problem. It provided tools to connect the systems, set parameters for the assessment, and interpret the results. The approach used builds on conventional LCA steps, however, it was extended to address multi-system parameters. The model introduced two contributions to a standard LCA approach. The first is an opportunity matrix which cross references literature interest areas with assessment indicators to help plan a system scenario. The second is assessment parameters unique to the model with which an intervention use case can be built. Finally, the model addressed aspects of system design for the contextual characterization of the assessment.

To examine the efficacy of the model, the third manuscript evaluated a temporary urban intervention case study which consisted of a vacant land and shipping container systems. The case study was used to validate the model and realize an outcome for the research. The assessment considered the environmental impacts of a temporary intervention system for a community space in a residential area. It addressed impacts of site production, structure construction, and all related transportation impacts. The assessment also compared the proposed intervention to conventional pathways of each system. The findings highlighted clear advantages of extending the life of shipping containers and their use over conventional structures. The results also highlighted the minimal impact of temporary interventions on lands for their use of unintrusive materials.

The overarching objective of this dissertation was to propose and experiment with the MSLCA model to evaluate the sustainability of temporary urban regeneration interventions on vacant lands using shipping containers as tools. The main contributions of this research can be summarized as follows:

- Framework for the analysis of an urban problem.
- Approach for the identification of development potential.
- Pathway for the generation of development strategy.
- Guidance on the identification of requirements, constraints and opportunities.

5.2. Impact of contributions

The research provided a systematic approach for a multi-stream life cycle assessment model of separate systems. This is to contribute to filling a gap for an assessment framework analyzing the cumulative impacts of separate systems. The research on temporary urban regeneration initiatives highlighted the complexity of urban systems and the unique characteristics of temporary interventions. It also observed key sustainability issues that are important in the analysis of urban problems and the identification of developmental objectives. Such exploration determined the direction of the contributions and aided in the model development. Although there is a number of available assessment models to evaluate the sustainability of urban systems, many consider specific aspects of these environments. These complex systems require a cohesive and interrelated analytical tool for the multiple aspects of any given urban context.

The proposed MSLCA framework utilizes a holistic modeling structure with a process to integrate and analyze separate systems and quantify results for an overall sustainability performance. In particular, it lays out the process for working with two separate systems to provide a pathway for a temporary urban development strategy. The process starts with a diagnosis of an issue to identify parameters of the observed problem. This sets the stage for programming and information gathering step which allows for the appropriate connecting of systems. The model also provides a process for system performance assessment and monitoring to guide decisions on the system. Finally, the results help inform an implementation strategy for the assessed system.

The application of the MSLCA model at the urban level focuses on guiding decisions to enable successful regeneration objectives. These objectives are generally recognized by interventions that feature quality built environments and provide amenities appropriate to the needs. However, the model contributes a systematic process to evaluate the components necessary to create environments that serve successful regeneration goals. These include environmental sensitivity by evaluating the impacts of the intervention on the environment. Also, it considers the economic feasibility by calculating value contributions and the capacity to stimulate the local economy. Finally, it observes social equity by creating inclusive spaces and activities that embrace the local culture and values.

The overarching contribution of the MSLCA model is providing a process for observing a problem in light of two or more systems that merge together to contribute to a potential solution. The proposed procedure is to be used to highlight elements of the problem, identify pathways for solutions, and examine outcomes. The focus of this research centers around temporary urban regeneration, however, the model's application can extend beyond this specific topic. It can be applied to issues where a number of systems can be merged to address a given problem. Also, this approach allows for experimentation with a number of systems. For example, to evaluate the potential outcome of an intervention based on a number of established scenarios, systems can be interchangeable as long as they contribute to the proposed intervention. This creates avenues of unexplored opportunities in life cycle assessment research. Another contribution of the model is its ability to address specific phases in both systems to create the intended intervention for the assessment. Such phases are often transitional, so that any proposed intervention addresses unproductive phases to better improve efficiencies and achieve sustainable goals.

5.3. Limitations

Research still lacks an adequate understanding of temporary urban regeneration. The dissertation observed deficiencies in a clear and consistent position on the role of temporary interventions. Such constraint is brought about by a lack of holistic approaches for measuring outcomes. This is due to the complexity of the topic and the breadth of issues involved. The research revealed that urban interventions are best measured holistically in order to make well-guided decisions. This includes not only assessing environmental impacts but also economic productivity and social utility. Although the assessment only addresses environmental impacts, the model supports a comprehensive and reproducible life cycle assessment framework for temporary urban regeneration on the basis of unproductive stages of contributing systems.

Most available approaches operate in isolation from these components by addressing one aspect of regeneration without considering inputs from other components or feedback from other systems. The availability of process data is one key contributor to such limitation as it is pivotal to the accuracy of the assessment. This is due to the need for large amounts of "multi-faceted" data to be collected and analyzed. Generating data for systems life cycle stages at the microscale level was useful in understanding the impacts related to the intervention, however, there is a need for a tool to aid and streamline data collection at the macroscale. This is practically important for urban data as many site attributes are often unquantified. At the current stage, this research is considered at the pilot stage and is in need of an access to a comprehensive dataset at the appropriate stage of the system for external validation to be conducted.

5.4. Recommendations and future research

Most challenges imposed by urban systems operate in cycles of environmental, economic, and social principles that are embodied in the notions of sustainable development. Examining the relationships between these intersecting principles of sustainability is important in the analysis of regeneration impacts. For example, there is an opportunity for research to examine the relationship between environmental protection and economic productivity. The environmental viability of temporary urban interventions can be highlighted in the ability to redirect waste products while producing economic value. Similarly, the relationship between economic productivity and social utility can be highlighted in the potential to assimilate stakeholders' needs even to users with limited economic means. Finally, the relationship between social utility and environmental protection entails that social goals must innately be of environmental value.

The objective of attending to these intersecting parameters through unexplored utilities of contributing systems can be highlighted beyond their physical conditions. Changes in involving parameters of the assessed intervention should be carried out through processes of contextual analysis focusing not only on the urban boundaries but also on opportunities to link urban improvements to environmental protection, economic production, and social utility. In many cases, improvements brought by changes to involved parameters are not limited to the physical boundaries of the urban environment. Therefore, there is an opportunity for future research to consider a broader system of connecting parameters and including a multitude of related systems beyond the scope of a specific site. This is one of the early studies of its kind to apply an LCA approach in this manner, therefore, it represents early steps in the evaluation of meanwhile urban spaces. Particularly when it is goal-oriented and target-setting to deal with conflicts and advance sustainable solutions.

Providing a comprehensive model for assessing the impacts of temporary interventions and their conformance to sustainable regeneration paradigms is not an easy feat. This research affirms that such a framework is not without challenges and compromises. The main challenge is creating an overarching process that can be tested on a site and adapted to different settings and systems. Managing such a process is more successful when approached through effective partnership and engagement with stakeholders. Public inclusion through communicative, collaborative, and participatory processes ensures fairness and equity if the decision-making process through inclusive solutions that address relevant issues. In order to overcome this challenge, any proposed process needs to have five characteristics. First, focus on short-term goals while considering long-term benefits. Second, select accessible sites that have a potential to contribute to overall regeneration goals. Third, it needs to be capable of multi-scale application and operate at the site and contributing system levels. Forth, it needs a capacity to adapt to any changing circumstances and be less determinative. Finally, any proposed process needs to be open sourced and easily accessed by stakeholders. These recommendations wish to aid in the development of a set of reproducible multi-system assessment models for temporary urban regeneration.

5.5. References

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