Approaches to Systems Thinking in the Creative Design Process

New Methods in Problem Solving

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Abstract

Sustainable transportation solutions for the future will likely need to function as seamless systems for the convenience and pleasure of the customer. Therefore, new innovations in transportation and mobility must be considered as part of an overall system, which adds levels of complexity to the design development process. Systems Thinking is a growing topic within the Industrial Design field that enriches the design process by considering how a complex entity operates as a whole and how it interacts with its surrounding environment. This paper presents an overview of Systems Thinking and demonstrates how this method can be adapted to the design process to develop innovative solutions to transportation. Examples will be presented as case studies from the *'PACE Systems and Mobility Collaborative Project,'* which challenged mechanical engineering and industrial design students from the University of Cincinnati to apply this creative approach to develop dynamic and sustainable transportation solutions. These case studies will clarify the importance and value of Systems Thinking.

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1. Introduction

The need for mobility has increased in recent years and continues to grow. This demands a critical analysis of the process for designing automobiles and mobility systems for industrial designers. Advancements in technology have made improvements to the way we travel with greater speed, quality, and efficiency. Transportation systems have evolved to meet these needs and for many of us the main mode of mobility is the automobile. However, many experts within the field of transportation design, including Dave Muyres, Dan Sturges, and the late William Mitchell are asking critical questions about mobility and customer needs. These questions include how efficient is the current automobile as it is operated within today's infrastructure, what makes a vehicle efficient, and how can we make vehicles more efficient. Experts in mobility also question transportation needs relative to how fast a vehicles need to be and what is an appropriate speed based on various functions. They also wonder how mobility options might change to accommodate a predicted increase in demand. The United States Census Bureau estimates the world population at 6,827,300,000 and this is expected to increase. This will only exacerbate challenges in transportation, such as pollution and congestion. Clearly we need new or alternative visions for transportation that offers customers safe and environmentally friendly options for getting around.

In the past automotive and industrial designers have traditionally limited their approach to design by only considering aspects that directly relate to the vehicle, including design aesthetics, features, platform, branding, and customer needs. They were, and still are, rewarded for designing products that sell in order to make money for the company. However what sells is not always good design. This limited approach has restricted some of the most talented automotive designers as they spend their careers editing or modifying past production models. Or they redesign the aesthetics and form to create a new vehicle that has carryover parts and platforms. This approach has proven to be very profitable, however designers are becoming more aware of the overall impact vehicles have on the environment and are looking for new approaches to the design process that are conducive to creating new types of vehicle systems with excellent solutions to current mobility strains.

Today new challenges relating to transportation and the environment make this traditional approach to design no longer effective, appropriate, and, in some cases ethical. Contemporary automotive designers are aware of the possibility of new approaches to the design process and now consider a broader perspective that includes not just the vehicle, but also the environment that the vehicle will operate within. Widening the area of focus beyond aspects limited to the product is more likely to produce new and innovative design solutions that function and operate more effectively within various surrounding conditions.

This paper highlights the traditional model of the industrial design process as it relates to product, automotive, and mobility design, and identifies new approaches to yield a better product. This paper also elaborates on the process of incorporating Systems Thinking into the design process allowing designers the ability produce new results that address bigger challenges within transportation systems. These new approaches to design can be applied to products of any kind and crosses over into different disciplines that may have an influence on the product development process, including engineering, planning, and marketing. The application of Systems Thinking to the design process provides industrial designers with a new perspective and a higher level of awareness with regards to design, which can ultimately empower them to implement better mobility options. By applying this revolutionary concept of Systems Thinking to the design process, designers will have a more powerful and positive impact on the future of transportation.

2. Infrastructure and Mobility Challenges

When discussing broader issues concerning transportation, the topic of infrastructure usually comes up. Infrastructure addresses basic physical structures and facilities including buildings, roads, and power supplies that are needed for the operation of a society and organizations. In the past, industrial designers would consider this to be a system they cannot change because issues dealing to roads and highways typically fall outside of the scope of the traditional industrial design process, especially within the corporate workplace. However, designers can have an impact on the evolution of infrastructure. Knowing some of the history of infrastructure can assist designer in doing this, even if it is not specific to automobiles and includes light rails, pedestrian walkways, bike trails, and semi trucks. Understanding some of this history can inspire future changes and improvements, which could strongly influence vehicle designs.

Car proportions can be traced back to chariots and covered wagons, since this mode of transportation had an established width or the distance between wheels that created ruts in the earth. These ruts eventually became roads. Albeit a primitive infrastructure, this had a powerful influence on how road systems grew. As with many developing regions or countries a network of trails, roads, highways, interstates, bridges, tunnels, and the like were created to accommodate mobility needs. These networks grew over time to meet mobility needs, but the width of these roads did not. Ironically, the width of vehicles today is similar to the covered wagons of the past because they were designed to accommodate this preexisting system of roads.

In developing countries today there is a tremendous opportunity to implement alternative modes of mobility since restrictions from a mature infrastructure do not exist. From a global perspective, the history of an infrastructure system may vary widely due to many differing influences, including culture, terrain, funding, and the timing of various developments. Transportation infrastructure within the realm of automotive design is often overlooked during the design process even though it has in many ways evolved in parallel with the automobile. For the purposes of this paper, the focus will be on Interstate highways and transportation systems within the United States.

Industrial designer Norman Bel Geddes made a new vision for mobility and infrastructure visible when he created *Futurama* for the 1939 New York World's Fair. This famous and enormously influential installation was part of the General Motors Pavilion. It was a very progressive display for that time that promoted advancements in highways and transportation, as it introduced among other things a network of expressways that connected the nation. Although this vision may not seem very progressive today, at the time this display introduced strong indications for what the future of mobility could be, including aspects of the Interstate Highway System. This vision included highways with exit and entry ramps where vehicles could get on and off at 50 mph and where a motorist could pass though a city without having to slow down. These past predictions are basic aspects of the interstate today. It is likely that *Futurama* had a critical role in gaining public acceptance of this new vision.

Interstate development got its jumpstart in 1956 when President Eisenhower signed the Federal-Aid Highway Act of 1956, also known as the National Interstate and Defense Highways Act, authorizing the funding for approximately 41,000 miles (66,000 km) of Interstate Highways. The original intent was for military and defense purposes and would be paid for through new taxes. Construction was planned for 20 years, and by 1976 Americans discovered a new way of traveling distances with much more ease than was offered in the past. Apparently the effects of such advancements could not have been foreseen and accommodations were made for these new freedoms in mobility through an increasingly complex infrastructure. With this came political backing and funding under the mission of military defense, even though Americas unexpectedly dominated this network for their leisure, travel, and work. It is difficult to believe that recreational uses were unanticipated given the popularity of *Futurama* just 17 years before the Federal-Aid Highway Act. If this infrastructure would have been created for both military and the public uses, and Systems Thinking methodologies applied to the design process, it is interesting to consider how this system would have evolved differently.

Over time this infrastructure that allowed for newfound flexibilities developed obvious flaws, which include congestion, pollution, energy consumption, and parking. These problems in mobility have existed for many years, and yet consumers and automotive manufactures largely ignore them. Cities currently put a great deal of energy and resources into construction for the widening and maintenance of existing roads to accommodate an increasing number of cars and trucks, thus supporting this flawed mainstream mode of transportation. However, there are tremendous opportunities to incorporate alternative mobility systems that include safe lanes for neighborhood electric vehicles, integrated bike paths, and small urban vehicles.

Many planners envision cities in the United States to have high-speed trains that connect major cities, a variety of rail systems, safe bike paths, and intersections that are pedestrian friendly. Industrial designers stretch their visions to include cities with speed restrictions of 25 MPH, which is close to the average speed within an urban environment. This reduction in speed would allow for new types of small cars including narrow lane vehicles (NLV) with tandem seating and cars designed specifically for errands called 'near cars' or neighborhood electric vehicles (NEV). These options would be safer, smaller, lightweight, and consume less energy. Efficient transit systems and mixed modes of mobility address many of our current challenges, and are arguably what every major city should already have available today. Many cities in Europe and other areas of the world have developed systems like this, so cities that are just now planning for these improvements are only just catching up. General improvements in infrastructure are strongly encouraged to accommodate the anticipated population increase. Furthermore, there is a sense of urgency on this development when considering that the creation of new infrastructure systems will likely take 30 or more years. At this time advanced innovative solutions are not being introduced into the urban infrastructure. This raises an obvious question, how do we inspire the implementation of creative visions of the future with solutions that address current mobility challenges?

Issues related to parking, congestion, and pollution stress the need for a new vision for transportation. On average vehicles are parked approximately 90% of the time (Mitchell, Borroni-Bird, and Burns 2010), and within congested urban areas, it is often expensive and difficult to find parking. The allocation of prime real estate in urban areas for parking lots and parking garages manifests in poor land use for the society as a whole and high daily, weekly, or monthly costs for the private individual. Driving around looking for parking spaces wastes time and energy, and adds to traffic congestion and air pollution. There are numerous ways to improve parking in urban areas. Today, autonomous vehicles have proven to be a very realistic option to introduce within the transportation system. An autonomous vehicle could drop the driver off at their destination eliminating the hassle of parking. If autonomous vehicles were part of a ride share program these passenger cars would move from one person to another without the need to park. This would require fewer parking lots within an urban infrastructure. Existing parking lots that were no longer needed could be converted into green spaces or used for new architecture.

Congestion during rush hour within urban areas obviously makes for slow commutes, frustrated drivers, and contributes to 'road rage'. This also lengthens the unpleasant daily commute and adds to pollution. A product that emits poisonous gasses into the air is not, by many standards, a good design or an efficient product. Vehicles release carbon dioxide contaminants contributing to poor air quality and health problems, while causing instability and harm to the natural environments and ecosystems. This misuse of limited natural resources is contributing to their depletion and global warming. Cars and trucks are designed to contribute to air pollution and our infrastructure is designed to produce congestion forcing longer commutes. Ironically, technologies exist today, such as the electrification of vehicles, which would allow for the production of vehicles that could have zero emissions. Also, if commuters drove smaller vehicles, carpooled, or took the public transit system, this would reduce or eliminate traffic congestion. However, consumers, designers and automotive manufacturers are challenged with introducing these products into the market place largely because the current infrastructure does not accommodate these innovative products.

3. Sustainable Design and Development

Sustainability in ecology describes how biological systems endure and remain diverse and productive. For human beings it refers to the potential for long-term health, comfort, and overall wellbeing. The quality of life for humans in turn depends on the quality of the natural world and the long-term use of natural resources for the future. Sustainable development considers the use of resources that meets human needs while preserving the environment. The term was used by the Brundtland Commission, which defined sustainable development as meeting *"the needs of the present without compromising the ability of future generations to meet their own needs."* (World Commission on Environment and Development 1987) This idea embraces the concept of designing products in the present while considering the effects of the product throughout its entire lifecycle and implications it may have after its use. Industrial designers who design sustainable products consider aspects of the built environment to comply with the principles of economic, social, and ecological sustainability.

When considering these definitions, are automotive and transportation designers creating sustainable products? Do vehicle manufacturers consider the environment or infrastructure that cars and trucks will be operating in during the design development process? This may be addressed in terms of the width of a vehicle so it fits on the road, or the ceiling height of a residential garage to accommodate the opening of a hatch door. But when considering aspect of sustainable design, how is this reflected in new products? Minor improvements in fuel economy through complex hybrid or electric vehicles are incremental improvements and are a long way from the immediate solutions needed to address the broader range of challenges relating to mobility.

Sustainability aims to improve the quality of life and wellbeing, requiring a change in perspective or mind-set towards higher standards and values (Schor 2010). Over time these values have eroded as consumers have accepted pollution from vehicles in order to maintain a lifestyle or perceived freedom of movement. But how free are consumers when they are stuck in traffic and breathing poisonous gasses? In the bigger picture of the current situation is this really an attractive lifestyle? Innovations in mobility products can address this challenge and at the same time enhance the quality of life. Advanced technologies also offer solutions to many mobility challenges. Offering efficient multi-modal transportation systems may serve as a catalyst for positive change, making it easier for commuters with options other that the car. This could also influence what types of transportation products are offered to consumers and how they are used. For example, consider the possibility of system that accommodated single passenger vehicles (SPV), portable mobility devices, neighborhood electric vehicles, e-bikes, and bicycles seamlessly and safely. All of these options could theoretically offer better and healthier lifestyle choices relating to mobility that are also sustainable.

Ironically, many industrial designers often pursue careers in this field to improve the lives of others through the products they design. Within the arena of sustainable transportation design there are incredible opportunities in realizing this goal. Industrial designers can have an enormous influence on sustainably designed products especially early on in the design process. *"Eighty percent of the environmental impact of the products, services, and infrastructures around us is determined at the design stage."* (London: Design Council 2002) Design decisions made at the beginning phases of the process determine the product function, materials, how they operate, and what happens to these products when they are no longer needed (Thackara 2005). Also determined at this phase is the amount energy needed to manufacture the product in addition to the amount of energy needed to operate the product once it is produced. The inclusion of sustainable design principles in the early stages of the design process invites new approaches to the creation of products. This also brings to light innovative options within an advanced development process, leading to the implementation of creative and sustainable products.

4. Systems Thinking

Ludwig von Bertalanffy (1901-1972) was a biologist who was widely recognized for his development in General Systems Theory (Minati and Pessa 2006). This defined new applications to numerous areas of study emphasizing holism as an approach to examine parts of a system in their context, as opposed to reductionism that consists in taking apart and reducing elements of a system for analysis. Looking at systems also emphasizes organisms as a whole with interdependent parts over mechanisms and machinery. In Systems Thinking, properties of the parts can only be understood by looking at their relationships with the whole system. In complex organized systems, new properties emerge from the interaction of the parts (Capra 1996).

Systems Thinking is a trans-disciplinary approach to problem solving that encourages research strategies from many disciplines to create a holistic approach. This approach allows for a better understanding of contemporary problems associated with extremely complex systems that cannot be solved from one point of view or by one discipline. It brings together people with different backgrounds, including transportation designers, scientists, practitioners, political and community leaders, business and industry representatives, engineers, and biologists to address local, regional, and global problems. When Systems Thinking is applied to the design development process and multiple disciplines are involved, the designers are more informed through the diversity of viewpoints.

From the perspective of an automotive designer who is working within the corporate environment, the scope of their responsibilities are usually limited to aesthetics, vehicle proportions, door cuts, ramp angles, occupant visibility and other related elements that relate directly to that product (Figure 1). Changing one of these elements on the product often impacts other areas of the design. Vehicles alone are very complicated products that have multiple systems within them and very specialized skills are required by the industrial designer to obtain optimal functionality as well as aesthetic grace. Design or engineering modifications in one area of the vehicle drives design changes in other areas of the vehicle. These design alterations are made with consideration to specific vehicle specifications. Vehicle platforms, dimensions, and proportions are often times locked in by the time the project brief reaches the industrial designer. This makes it very difficult for a designer to make large changes to the product because they are working from a preexisting package.

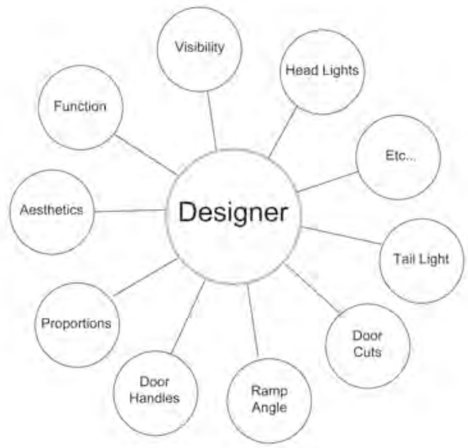

Figure 1. When car designers focuses on aspects limited to the vehicle the opportunity to incorporate aspects of sustainable design and development are not easily achieved.

Applying Systems Thinking to automotive design will expand design influences beyond just the product. This design approach to mobility is growing with great momentum (Figure 2). Parameters that limit a designer's level or awareness to only aspects relating to the product reflect a traditional design process, which may compromise the effectiveness of the final product within its environment. When considering aspects beyond the product, such as infrastructure, congestion, parking, and sustainable development we begin to ask different questions that influence the entire design development process. This will lead to new questions that designers traditionally don't ask. For example, how important are aerodynamic qualities when cars are stuck in traffic or when the average speed within an urban area is less than 20 mph (Mitchell, Borroni-Bird, and Burns 2010)? How do we solve the problem of congestion on highways and in urban areas? If cars are parked approximately 90% of the time, how can we make this parking time productive? If vehicles are most often driven with one occupant, can we eliminate multiple seats and storage areas to reduce mass and costs? These questions need to be asked very early on in the design process. Visualizing products as answers to these questions can have massive influences on the development of design briefs, which can drastically change the design process (Figure 3) and thereby change the consumer paradigm.

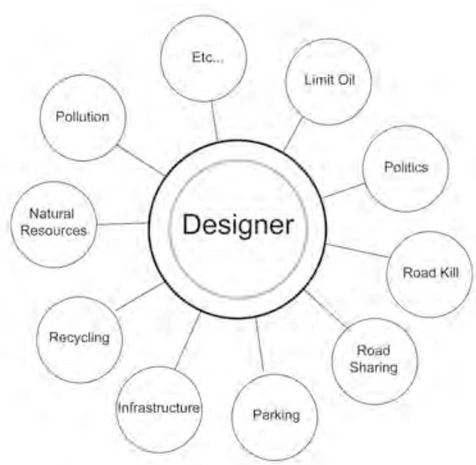

Figure 2. When applying Systems Thinking to the design process, industrial designers broaden their area of focus to include aspects beyond the product. This allows for the opportunity to incorporate sustainable design principles within the design process.

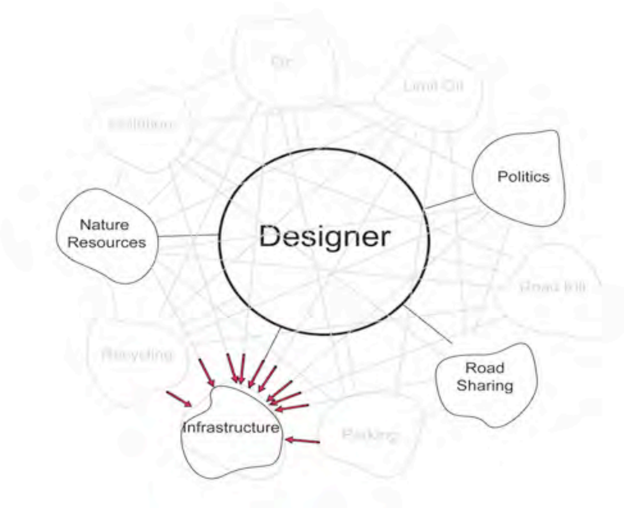

Figure 3. Thinking outside of the 'product bubble' can cause massive changes in the design process and increase the chances for appropriate product solutions to current mobility challenges.

There are many different systems with unique conditions that, when considered during the design process, can broaden the perspective of an informed or aware design team. During various phases of this process the area of focus may shift from one system to another to varying degrees. This influences changes in the product as a whole and ultimately drives product innovation from this broadened point of view. To develop sustainable transportation systems that truly improve the quality of life for the user, designers must include these broader aspects such as recycling, disassembly, energy consumption, and emissions. They need to ask the hard questions about the efficiency of an overall vehicle relative to the customers needs and create appropriate and sustainable mobility solutions. This comprehensive approach to vehicle design will result in higher quality products that are suitable for various environments. When Systems Thinking is integrated into this process the industrial designer and collaborative partners are much more aware of how their products are contributing or inhibiting the quality of life for the consumer.

5. Observing Systems

Emergence is how patterns in complex systems develop from simple interactions within the system. Emergent phenomena are unexpected and observable (Jaspart 2010). How the observer interacts with the system directly affects the result of what is being observed. There are three different scenarios of observing systems and their emergent properties that produce different results.

The first scenario is when the observer is outside of the system (Figure 4), making it more difficult to adapt ideas to a product. In this way the observer's ability to study the system is weak. An example of the effectiveness of this approach to observation would be a designer creating a vehicle for China when they have never been to China to experience the culture and environment. This would pose some obvious challenges making it difficult to produce an appropriate product for this market.

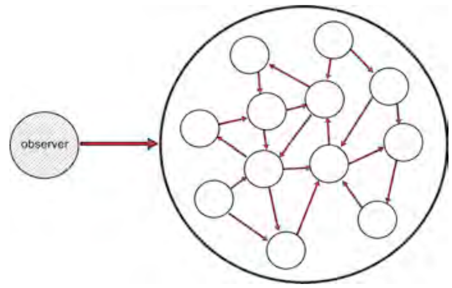

Figure 4. The observer is looking at the system from outside, resulting in weak observational conclusions.

Second, the observer is inside of the system (Figure 5), making it easier to scrutinize system properties, resulting in stronger observation abilities. In this case results or outcomes are stronger and concepts or ideas can be easily adapted to products. However, there is concern with the observer interacting in the system and altering an outcome, so special considerations should be made to methods to avoid this problem. For example, if a designer goes to China with the intent to design a vehicle for this country, he or she should be able to assess the culture without altering it. This would enable them to design a product appropriate for that environment. It becomes problematic if the designer changes the environment. This is likely to result in weak observable results, and designers are likely to produce products that are less appropriate for those specific surrounding conditions.

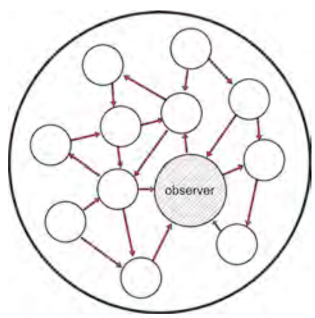

Figure 5. Results from systems observed from inside are strong as long as the observer does not alter their surrounding conditions.

In the last case there are two observers, one inside the system and the other outside the system (Figure 6). This arrangement is the strongest way to observe systems. The observer on the outside can give input to the observer interacting within the system and eliminate the possibility of altering any outcomes. Any limits to the observer's position form the outside are offset by the observer's viewpoint from within the system. Ideas resulting from this level of observation are likely to have the best results.

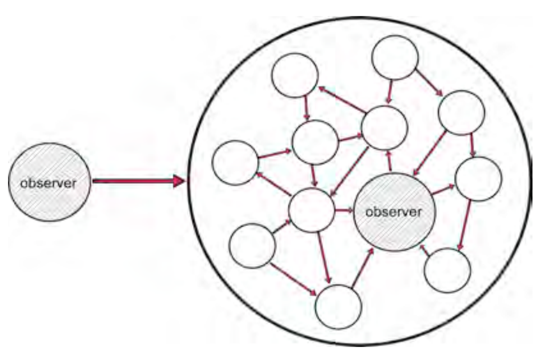

Figure 6. Emergent patterns observed from inside and outside the system yield the strongest results.

6. Applying Systems Thinking to Mobility Design

Within the transportation design studios at the University of Cincinnati sustainable development is a main theme throughout the creative process. This has a very strong and positive influence on final concepts. Addressing the principles of sustainable design within this process has many obvious benefits. However if sustainable products are created without incorporating Systems Thinking into the development process the generation of new ideas and methods is inhibited. The creation of novel products with innovative attributes appropriate to the environment it will be operating in are more likely to result when applying Systems Thinking to the design process.

The following examples describe two products from the industrial designer's perspective that were developed within the *Systems and Mobility Collaborative Project* that was supported by Partners for the Advancement of Collaborative Engineering Education (PACE). This collaborative project challenged mechanical engineering and industrial design students from the University of Cincinnati to develop dynamic sustainable solutions to transportation problems by applying Systems Thinking methodologies to the design process. These projects clarify the importance and value of Systems Thinking in designing sustainable mobility solutions for the future that will function as seamless systems for the convenience and/or pleasure of the customer.

Gregory Martin applied Systems Thinking by focusing on parking and energy infrastructure as it relates to commuters. General research on parking lots identified numerous challenges around this topic. The views of parking as shown from above in Figure 7 demonstrate that these parking lots separate the church from the community it serves. Parking lots for churches are largely empty for most of the week, giving proof of poor land usage. Figure 8 shows the parking lot arrangement for a Wal-Mart, which is also a poor use of land without consideration to watershed, water absorption, shade, and pedestrian pathways. In both of these photographs, the parking lots remain mostly vacant the majority of the time.

Figure 7. Parking lot of a church separates the church from the community it serves.

Figure 8. This image shows the size of a parking lot for a Wal-Mart store, which is arguably not a good example of efficient land use. Images created by artist Travis Shaffer.

When applying Systems Thinking, numerous solutions to the challenges of parking lots can be considered. First lets explore some of the most obvious solutions. Most parking lots are designed for vehicles and do not consider the human experience relating to parking. Planning for shaded pedestrian sidewalks and crossings would make the experience of parking more safe and pleasant. Alternative and natural materials used in addition to or instead of asphalt or concrete could allow for water to be naturally absorbed into the ground in addition to redirecting water runoff. Incorporating rain gardens and wall gardens into the landscape would filter polluted runoff water from parking lots and buildings before entering local rivers and streams. Landscaping with trees and gardens create wildlife habitats and shaded areas while improving air quality. These are just a few ideas that are not revolutionary, but do take time and consideration to plan, develop, and implement. It's much easier to roll out the black top and calculate predictable maintenance costs, but it's not the best result in the long run. When new ideas like these are incorporated into a system, there are new maintenance considerations and possibly additional costs. Good design often includes cost saving measures to sustain these improvements. Sustainable solutions that enhance the quality of the customer experience are clearly better design and can lead to greater customer loyalty.

Considering how a vehicle operates within parking lots is an example of Systems Thinking. Greg Martin's main focus was on aspects of the vehicle while keeping in mind the challenges of parking. He focused on an electric personal mobility vehicle within the urban environment and designed a small tandem seating two-passenger vehicle (Figure 9) based on research revealing the fact that most commuters in the United States travel with one person in the car more than 90% of the time (Mitchell, Borroni-Bird, and Burns 2010). In Greg's concept the second seat could be reconfigured to accommodate cargo, which adds functionality and versatility. Reducing the footprint of the vehicle decreases the overall size of each parking space needed. In this concept a typical parking spot was split in half, which reduces the total size of a parking lot in half. This theoretically would cut cost for purchasing and maintaining the parking lot by 50%. Additional benefits include the reduction of mass and weight of the overall vehicle, which leads to less energy consumption.

Figure 9. This exterior concept rendering by Greg Martin is an Electric Personal Vehicle (EPV) to operate within an urban environment. This vehicle is a small tandem seating two-passenger vehicle.

Greg also incorporated electrification of the parking system (Figure 10) to charge vehicles while they were parked. Human Machine Interfaces (HMI) designed within kiosks and the vehicles assist drivers in finding available parking spaces, in addition to displaying energy usage and needs. Solar panels on the tops of these vehicles collect energy while the vehicles are parked and ideally give energy back to the grid. This could be a large cost savings to the customer or vehicle owner. Numerous parking structure options can be researched and invented for vehicle storage under and above ground. These can vary in shape from rotating cylindrical structures to shelving units. Augmented reality can be designed to project street signs and directional arrows to guide the driver to a parking destination. Virtual vehicle avatars can be created to assist in navigation or autonomous vehicles can drop occupants off at their desired destination and either park or pick up other passengers.

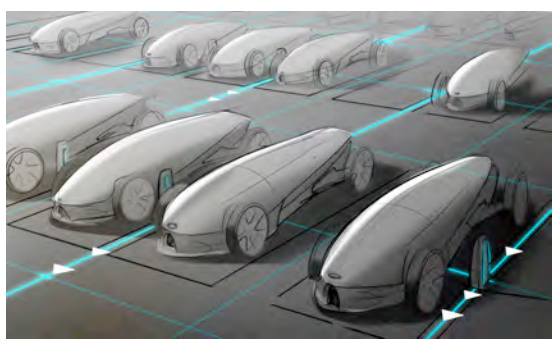

Figure 10. Concept rendering developed by Industrial Designer Greg Martin. This image shows a parking lot system that incorporates an electric grid for charging vehicles that utilize this space.

Peter Tabeling used Systems Thinking while focusing on trains. Instead of targeting commuters who would utilize trains for daily commutes, Peter focused on students within the United States and the educational system in the state of Ohio (Figure 11 and 12). He observed how students move to and from different academic institutions, places of residence, and employment throughout the academic year. He noticed how individuals traveled both regionally and nationally with their belongings packed into a vehicle that they would drive to their destination. Often times their cars are stored while these students are living in an urban environment because they are simply not needed until the student packs up and relocates once again. This is typical for students who participate in cooperative or internship programs within higher education. The additional costs incurred for insurance, car payments, parking, and maintenance of a vehicle while in storage is considerable

Peter envisioned a better solution to improve the quality of life for these students, while enhancing the educational experience. He designed a network of tracks that connected major colleges and universities within the state of Ohio and focused on the needs of these students within this structure.

Figures 11. Map of Ohio showing the location of major universities and how they could be connected through a network of trains and rail systems.

Figure 12. Concept renderings by Peter Tabeling. This modern train would be part of a network of trains connecting major universities in Ohio.

If Peter had focused on trains alone, it is likely that he would have developed design solutions appropriate for this challenge. However, because he broadened the scope beyond the train to include the educational system, the final design included novel attributes that would not otherwise have been developed. Peter grounded the design process by incorporating Systems Thinking approaches to planning, designing, and developing the train to meet the unique needs of students who were attending college.

This research led to the development of three main functionality themes relating to; 1) the passenger riding experience, 2) how the vehicle is transported, and 3) how cargo and student belongings are shipped. Peter researched various scenarios and created systems for each theme, which he described in storyboards (Figure 13). This approach to the process allowed Peter to design systems for each theme that were easily understood and user friendly.

Figure 13. Storyboard concepts developed by Peter Tabeling that details the passenger experience relating to three main functionality themes; 1) the passenger riding experience, 2) transportation of the students vehicle, and 3) student cargo.

Passengers traveling on these trains would use a card swipe system or a scanner for smart phones to enter the train station area and to purchase tickets. All of their account information would be easily accessible from their smart phones. They would then enter the assigned or desired section of the train. These sections could include free wifi throughout and special areas designed with workstations so students can easily do homework in isolation.

Peter's train concept provides an alternative to costly cars, in addition to ferrying students and their cars to various universities within the state. Students often have to transport their own cars so they have them available to use while they are attending school. Special cargo containers were designed to ship vehicles easily. Students could drive their vehicle to the train station to a designated platform where the cars could be driven onto one of these containers. When they drive onto the cargo container it would arrive on a turntable that would rotate the car 90 degrees so it is in-line with the container and can be easily driven into parking position. Students looking to save money could stay in their vehicles for the duration of the trip with limited access to vending machines and rest areas. When the train arrives at their destination the vehicles can be easily offloaded by use of the turntable and the student would drive their car off the train and onto the platform that would lead them to the road. As new mobility options are introduced into urban areas the need for the traditional car will decrease, which will eliminate the need for transporting personal cars altogether.

Moving personal belongings can be a hassle for students who move often for internships or for transferring to different universities. When shipping personal belongings from one university to another students would order a shipping container online that would be delivered to their home. They would load the cargo container and schedule for the container to be picked up and transported to the train station where it would be loaded on to the appropriate train. Upon arriving at the designated destination this container would be delivered to the student's new residence where it can be unpacked. The container would then be scheduled for pickup. This seamless system for moving personal belongings is much easier then having to do it with a traditional car.

Additionally Peter designed the interior of the train to accommodate the needs of this market, which influenced the overall interior form by including areas within the train where students could access advanced computer technologies and comfortably work on their own computers. Sound diminishing materials were strategically placed to limit the amount of noise around the passenger as they worked on the train. Sound enhancing materials were included so riders could easily hear announcements. Ultimately, this system was designed to enhance higher education by removing obstacles between students and universities, allowing for greater access to a variety of educational options. This system could potentially unify colleges with a network of trains connecting them into one cohesive statewide college system. This system would also accommodate passengers who are commuting long distances as well as other professors and staff within the university environment. These riders would also desire the user-friendly features that were developed for college students.

7. Conclusion

Alternative and sustainable transportation design solutions for the future are needed and will ideally function as seamless systems for the convenience and pleasure of the customer. Sustainable solutions are currently being developed in incremental steps when industrial designers work within the framework of the traditional design process, but these designs are less likely to be groundbreaking solutions addressing the comprehensive challenges of our time. The established design process includes only aspects that relate to the product and does not consider how the product may operate within a given system. New approaches are needed to allow the designer to consider facets beyond the product and include elements of the environment that the product will be operating within.

New techniques and approaches in the design process embrace this broader perspective and act as catalysts for innovations in product, transportation, and mobility design. Systems Thinking is one such approach that when applied to transportation design addresses modes of mobility as part of an overall system. These systems can be observed, analyzed, and incorporated into the design process to develop new product solutions. Systems Thinking is a growing topic within the industrial design field that enriches the approach to problem solving by considering how a complex entity operates as a whole and within its surrounding environment. Advanced and dynamic sustainable mobility solutions manifest by applying this creative approach to design.

Integrating Systems Thinking methodologies into the design process incredibly challenging. Furthermore, taking these innovative concepts and putting them into production can be an even greater task. Introducing these elements into the studio setting can be especially difficult in the corporate environment where profits and sales drive design innovation. It is much easier to design products in isolation while ignoring aspects of its broader use and impact. But how much longer can we continue supporting a design process that theoretically improves the lives of others in the short term, but comes at a cost in the long term?

Traditional cars do not solve the problems of congestion, pollution, energy depletion, or global warming. In fact they contribute to these complications. When we operate under the ‘business as usual’ model it is much more difficult to create new products that are the long awaited answers to the challenges of our time. Systems Thinking is a powerful tool for designers to utilize as a catalyst for inventing products that minimize or eliminate mobility challenges of today. These sustainable products are more likely to improve the quality of life for people of today in addition to future generations to come.

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Figures 7 and 8 by Travis Shaffer, http://travisshaffer.com/

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