STRATEGIC APPROACHES TO DEVELOPING FUTURE MOBILITY SOLUTIONS BY APPLYING SYSTEMS INTEGRATION AND THINKING METHODOLOGIES

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1. FUTURE MOBILITY AND URBAN DENSITY

Personal mobility is likely to change in the future, especially within the urbanized world. These changes are most likely to occur due to expected increases of urban density that will cause stresses on megacities as they expand. This topic of urban growth is elaborated upon in *Reinventing the Automobile, Personal Urban Mobility for the 21st Century* by Mitchell, Borroni-Bird, and Burns when they state, *"The United Nations projects that 60% of the world's population will be living in urban areas by 2030."* Predictions for the number of people living on the planet in 2030 are estimated to be eight billion. This will create tremendous pressures in the form of pollution, energy security, consumption, congestion, and traffic safety. This will also challenge public infrastructures that are already struggling to meet the growing demands for transportation and basic mobility services. These megacities will be so dense that the place for the traditional car will rapidly decline. To accommodate the expected increase in urban density, plans for investing wisely in basic core infrastructure needs should be considered now.

In *The Dynamics of Global Urban Expansion,* Angel, Sheppard, and Civco discuss the forces that will influence urban expansion. *"Aspects of the transport system that affect urban expansion may include the introduction of new transport technologies…*" Transportation costs, the amount of government investment in roads, and reliable public transport systems are aspects expected to act as catalysts for improvements to the existing infrastructure, however, there is an enormous opportunity for product and transportation designers to develop and implement new mobility options that are solutions to these global challenges. In order to develop innovative products a new comprehensive and holistic approach to the design process is needed.

2. THE TRADITIONAL DESIGN PROCESS AND SYSTEMS THINKING

Vehicles 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 when dealing with such complexity. From the perspective of an automotive designer working within the corporate environment, the scope of their responsibility is limited the vehicle, including the aesthetics, vehicle proportions, door cuts, ramp angles, occupant visibility, and other elements that relate directly to the product. From a systems thinking perspective these aspects are individual systems that must function as a whole. Door systems, storage systems, wheel systems, and window systems are only just a few of such interconnecting parts. Parameters that limit a designer's level of awareness to only aspects relating to the product reflect a traditional design process, which does not include aspects of how the product operates within its environment.

In a traditional design process changes often occur. Design or engineering modifications in one area of the vehicle drives incremental changes in other areas. These design alterations are made with consideration to detailed specifications. Vehicle platforms, dimensions, and proportions are often times locked in by the time the project brief reaches the industrial designer. Working from this pre-existing package makes it very difficult for a designer to develop new and innovative mobility options. No matter how many changes are made during the design process, the end product is a variation of what already exists.

The reality of current transportation is that the existing infrastructure was created to accommodate the way we use cars and trucks. Individual vehicle ownership has brought great freedoms and conveniences to the way people live and work. The car and truck industry is rich with talented people focusing on putting these products into production, and this becomes the seed of corporate profits. These jobs and earnings influence the economy. No doubt there is a critical need and market for cars and trucks, but what about other mobility options for people who don’t have cars or don’t want them? With mounting real world challenges like urban population growth, shouldn’t transportation be more sustainable?

3. APPLYING SYSTEMS THINKING TO COMPLEX STRUCTURES

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).

When developing alternative modes of mobility designers must consider changes to the traditional design process and include a holistic approach that goes beyond the product to include infrastructure, recycling, natural resources, congestion, parking, climate change, and pollution. Then the design team will ask new questions about the existing system and the realities of its positive and negative attributes. This inquiry can influence the entire design development process. 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? Visualizing new products as answers to these questions can have massive influences on the development of design briefs, which can guide the discovery of new transportation, infrastructure, and consumer paradigms.

Applying systems thinking to the design process by introducing these enormously complex issues, however, is much easier said than done. Often times when exploring these aspects of mobility designers lose direction and become unsure about how to react to such immense issues, making it difficult for any product team to understand these challenges in detail. Too many unanswered questions can lead to confusion. When this happens, priorities become unclear, and deciding what kind of product to develop is impossible. It can be exhausting to dream of new products that keep the better qualities of an existing infrastructure to accommodate cars and trucks, and improve upon the inadequacies. However, at some point the team needs to let these real world challenges influence the invention of new products that are solutions to these issues.

In order to keep from becoming overwhelmed it is often times best for the design team to identify specific aspects of the bigger picture that will have the greatest impact on global issues. This allows the team to accomplish goals as they develop new vehicle types or segments that address challenges in selected areas. Since there are several overlaps between different real-world challenges, focusing on one or two may likely have a greater impact on numerous global issues. For example, when electrification becomes the area of focus, this also addresses fuel economy and pollution. Vehicles that have a small footprint solve problems relating to fuel economy, pollution, parking, and congestion.

Introducing systems thinking into the design process is complicated, but necessary for a new approach to design. Keeping an eye on the bigger picture helps to guide team decisions and the new product development process. It is also beneficial to explore the finer nuances of mobility systems and how they are used. There isn't a straightforward approach to this mile-high perspective that must shift into a deep dive to explore details up close. However, there are some general practices that teams can use to help them in this pursuit.

In *The Fifth Discipline* Peter Senge states that *"Systems thinking is based on a growing body of theory about the behavior of feedback and complexity – the innate tendencies of a system that lead to growth or stability over time."* Senge also elaborates on ways of explaining qualities of real life and offers some guiding steps to explore this. Often when we look at a challenging issue we only see the events on the surface, which are usually hints of something much bigger. When a design team focuses on a specific topic it may prevent them from seeing the complex realities that are under the surface. Senge suggests looking closely in four steps: 1) Events or Situation, 2) Patterns and Trends, 3) Systemic Structures, and 4) Mental Models.

Events or situations can be of the past and/or present. We look closely at what is going on. From this perspective we are only seeing the surface and the general response is to *react.* For example, consumers respond to electric cars in a variety of different ways. Positive reactions may be that customers feel good about consuming less energy and not having to go to a gas station. They may be opposed to this idea because of battery replacements costs and recharging times. Even though these reactions are important to know and may be justified, studying events alone is not effective in developing new products beyond what currently exists.

To move forward we must look deeper at patterns and trends. This can be accomplished by looking at what has happened in the past. It may be helpful to make a diagram that clearly shows historic events relating to the topic. This will also give us the ability to a*nticipate* what might logically be coming next. Electric vehicles are not new. In 1916 the Detroit Electric car was extremely popular, but was shunned in 1939 when the combustion engine eliminated the need for a hand crank. General Motors leased the Electric Vehicle Generation One (EV1) from 1996-1999. Customers responded extremely positively to this car, however General Motors believed that the targeted market was an unprofitable niche and crushed almost all of these vehicles. Now we see other electric devices including the 2002 Autonomy Skateboard Platform, the 2009 Personal Urban Mobility and Accessibility (P.U.M.A.) and the 2011 Electric Networked-Vehicles (EN-V) prototypes. Only now are we seeing hints of these advanced technologies in production with the Chevrolet Volt, the Nissan Leaf, and the Tesla Motors electric vehicles. This is important information, but exploring patterns and trends does little to aid in decision-making. To go deeper we must consider what are the causes of the patterns.

Systemic structures are the forces contributing to patterns. Technological developments, corporate decisions for profitability, infrastructure, and a lack of customer awareness are systems that heavily influence the challenges in the implementation of electric vehicles. It is vital to understand how these systems have developed over time and how they have resulted in current habits that inhibit change. Understanding these existing practices will assist in redesigning and designing new systems. These structures may be difficult to identify, but can reveal points of greatest leverage. Senge states, "*Systems thinking is a powerful practice for finding the leverage needed to achieve the most constructive changes."* Considerations to the systemic structures reveal such leverage points and opportunities to design enduring products that make improvements to the comprehensive system.

Once we have explored the leverage points through systemic structures we are better informed as to what areas to target for lasting change. There is, however, an even deeper level. This level deals with the mental models that ultimately created these systems. Mental models include our thinking patterns, beliefs, attitudes, and values that allow the situation to persist. These are the drivers of our actions and controllers of our interactions with a system. Powerful leverage points can only be identified through the deep exploration and understanding of these drivers. Understanding these deep beliefs reveals the reasons why a person might be hesitant to purchase an electric vehicle. This approach identifies leverage points that when considered within the design process, can lead to the transformation of this way of thinking.

Exploring these four steps within the studio environment takes thoughtful consideration. During this part of the process students and professionals are not looking for solutions. Instead, they are generating a better understanding of the current situation relative the topics they are focusing on. From this deeper holistic perspective designers are more aware and better design solutions are likely to emerge.

4. THE PORTABLE ASSISTED MOBILITY DEVICE CHALLENGE

In response to predictions of increased urban density and the growing stresses this will have on the existing infrastructure General Motors developed a concept brief, which challenged students in design and engineering to generate ideas for a Portable Assisted Mobility Device (PAMD). This brief was created through collaborative efforts with Partners for the Advancement of Collaborative Engineering Education (PACE), a group formed by General Motors to help facilitate interactions between industry and academia. PACE invited selected academic institutions to participate in this challenge. The University of Cincinnati accepted this invitation and in the fall semester of 2012 a studio was formed and students focused on this project.

The PAMD project brief was extremely comprehensive. Within the guidelines students were expected to design an electric or power assisted device with a small footprint. These concepts were also expected to integrate with public transportation. Systems thinking and integration methodologies were introduced into the design process. This was essential in developing concepts that identified products and needs that would not ordinarily be addressed within the traditional design process. This systems approach was achieved using two distinct strategies. First, the integration with public transportation led to extensive research of the urban environment. This resulted in the direct applications of function or logistical aspects of blending these two systems so they worked seamlessly together. The second strategy included studying persona behaviour patterns and habits to connect the user with the product. Research concluded that educating the customer about these new products was a critical component. This was achieved through motion graphics, websites, and applications, which clearly outlined the intended use of each new device. The use of these graphic visuals helped to make each product easy to use and understand. User-friendly products are theoretically more attractive to the consumer and more likely to be successful within the market.

5. CREATING THE TEAMS AND THE JIGSAW CLASSROOM TECHNIQUE

This PAMD collaborative studio involved managing teams from Industrial Designers, Graphic Communication Designers, and Mechanical Engineers. To manage these teams, a cooperative learning technique was used to organize classroom activities and encourage positive interdependence among team members. There are several different cooperative learning models that could be used in this setting such as Think Pair Share, Reciprocal Teaching, and Round Robin. An approach that is commonly used in design studios is STAD (Student Teams Achievement Divisions). This process involves evaluating all individuals equally based on their team’s performance. In a good team this model works well when all of the teammates encourage each other to perform at their best, however, the STAD model can also generate resentment and inefficiency if a teammate does not show the initiative or the level of productivity that is expected by the group.

For this project the collaborative studio was structured after Eliot Aronson's *Jigsaw Classroom Technique.* This cooperative learning approach involved training group members separately in their area of expertise so each member returned and shared their unique knowledge with teammates. For example, the industrial design students attended classes and lectures in their classroom and then shared their knowledge with their engineering and graphics counterparts. The engineering and graphics students followed the same model and also attended separate classes. This process encourages listening and engagement with individual group members who have learned unique material essential for group success and created efficient group learning methods that increased the variety of educational experiences and design solutions available in the studio setting. The jigsaw method also enabled individual members to attend classes simultaneously instead of teaching all of the students sequentially. As a result, the instructors were able to use extra class time for group discussions and collaborative meetings.

6. THREE CASE STUDIES

The following case studies focus on the results generated by the industrial and graphic design students. The engineering team advised and informed each team throughout the semester, which helped to keep each student project realistic and functional. A total of 13 products were developed. Below are 3 examples of the unique concepts that were developed for the PAMD project.

Industrial designer Leon Wenning and graphic designers Kevin Danielson and Lindsey Melling conducted research to obtain a better understanding of biking in an urban setting. From this data they discovered bicyclists could not easily transport several bags of groceries or other cargo from small shopping trips on a bicycle, bus, or subway. Research proved this to be a dominant challenge for riders that depend on public transportation and their bicycle. The design team focused on this issue by exploring shopping habits and the use of grocery carts. They noticed that a typical shopper often picked up last minute items that were not pre-planned. This activity can be difficult for a bicyclist who does not have the extra space to carry these items.

After analyzing this data the team noticed that bike trailers address some of the issues discovered through research, but did not provide assistance when pulling heavy loads. Trailers also did not adapt easily to different shopping environments. As a result, the team developed a motorized bike trailer called *Cargo* that converts into a shopping cart. (Figure 1a and 1b) This design allows people to load their items in the store and immediately attach the cart to their bike outside the store. The process of loading and unloading items from a shopping cart to a bike trailer was eliminated with this design. The motor also provides assistance when pulling heavy loads, allowing the casual bike rider to use this device without strain or fatigue. A digital rental system outside grocery stores was also developed to provide access for users who own this device. (Figure 1c) This concept can potentially be adapted within any urban setting and appeal to a very broad market.

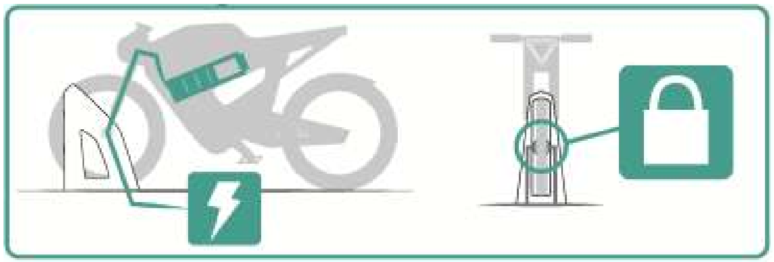
a. b. c.

Figure 1. (a) The *Cargo* bike trailer converts to a shopping cart (b) to be used in the grocery store. This concept is part of a rental system outside grocery stores (c) so bicyclists can easily have access to these trailers in places where they are most likely to be needed.

Ciclo Nova was a concept developed by industrial designer Miranda Steinhauser and graphic designers Brock Arthur and Kate Menkhaus. This design addresses issues related to urban transportation in South America. This design team researched various articles as well as community and regional planning publications for Rio de Janeiro. From this research they noticed that in the last decade, the number of cars in Rio de Janeiro has increased by 40%. As a result, traffic congestion has become a major problem. To address this issue, Rio has developed over 180 miles of bicycle paths that crisscross the city. This design was based solely on research articles and online surveys with individuals who live in that area. From this data the team found that the public would like to have a device that could travel longer distances and would give them the option to commute a portion of their journey with existing public transit systems. Using this data, the design team decided to develop a product that can be used on existing bicycle paths and travel longer distances without contributing to the air pollution that can exist in highly congested areas. The final design was a battery powered moped, which according to their research could legally travel on Rio's existing bike paths. (Figure 2a) This moped is smaller than a traditional motorcycle making it ideal for these bike paths. (Figure 2b) Charging stations were designed to allow individuals to lock up and recharge their moped when they use public transit systems (Figure 3a). The team also designed a mobile phone application that allows individuals to map out traffic patterns, existing charging stations, and transit lines on these bike paths. (Figure 3b) This feature was developed to seamlessly integrate this design with Rio's existing transit system.

a. b.

Figure 2. The final model for the *Ciclo Nova* concept (a) was built in Autodesk Alias and 3D printed as a 1/3 scale model. A package drawing comparison (b) shows the *Ciclo Nova* size, which is smaller when compared to a traditional motorcycle.



a.

b.

Figure 3. Charging stations (a) allow individuals to lock up and recharge their moped when they use public transit systems. Mobile phone applications (b) were designed to allow riders to map out traffic patterns, existing charging stations, and transit lines.

Product designer Winnie Chi and graphic designers Emily Scaggs, Elli Matejka, and Stephanie Szarwark created the Ebix electric bike concept (Figure 4a), which is a bike-share program for elementary schools. The primary interest for this project was to encourage bicycling and bike safety. The team conducted research to obtain a better understanding of biking in both urban and suburban settings in the Cincinnati area. This research included online surveys, interviews with parents and children, and a review of local accident reports involving bicyclists. From this data they discovered that many children were unaware of or did not practice bike safety. This included helmet usage, using hand signals, and understanding basic bike maintenance. They also noticed that children are more likely to be driven to school rather than riding a bike. To address these issues, the design team decided to develop a non-profit bike-sharing organization that would collaborate with local schools. Specifically designed for 4^{th}- 6^{th} grade students, the main component of this program included a power-assisted bicycle. After completing several safety training courses, these students would be allowed rent an e-bike for a year and during that time have access to an online community of Ebix users. This site would track miles so kids can compete with their friends on the website and win prizes for accumulated miles. (Figure 4b) Parents would also have their own online profiles enabling them to contact other parents within the program. After participating in this program for a full year, the design team believed that a healthy habit of exercise and bike safety would develop for both the parents and kids who participate.

a.

b.

Figure 4. This image (a) shows the design of the Ebix concept. The second image (b) is a screenshot of the ride-sharing program for kids in elementary schools in 4^{th} – 6^{th} grades.

7. CONCLUSION

Within the industry, automotive designers typically focus only on the production vehicle they are assigned to work on and do not consider aspects of the environment that their products will operate within. Of course, new experimental vehicle types and technologies are developed within advanced automotive studios. We see evidence of this in concept and production vehicles, however, these advancements are incremental and evolutionary. In order to address the issue of urban growth more drastic change is needed. New and innovative modes of mobility need to be developed and the infrastructure needs to be designed and built to accommodate these new ways of getting around.

Innovative and alternative vehicles and devices are needed for conserving an ecological balance. We are at a pivotal time when pollution, global warming, and the depletion of specific natural resources are current global challenges. In the future the anticipation of population growth and urban density will make these matters worse if we do not develop new habits. Innovative technologies and mobility products can influence and change the behavior patterns of large segments of the population. As these new products are put into production and introduced to the market, early adaptors are likely to be the first users. Getting these products into the mainstream market could prove to be a daunting task, however, integrating systems thinking methodologies into the automotive production design process could manifest into a significant shift in developing products that are better suited for the environment and successful within local and global mainstream markets.

Incorporating this holistic approach into the design process is incredibly challenging. Introducing various systems approach activities 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. This traditional design process approach may improve the lives of others in the short term, but comes at a cost in the long term. The numerous reasons innovative eco-friendly products are slow to penetrate the mainstream market go beyond the scope of this paper. Systems thinking methodologies gives the product team tools for a deeper understanding of our actions and the forces at play that influence our interactions of the system. This new design process will further the designers ability to identify leverage points that act as a catalyst for positive and impactful change.

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