Developing a transdisciplinary approach to improve urban traffic congestion based on Product Ecosystem Theory

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Abstract

Product Ecosystem Theory is an emerging theory that shows that disruptive "game changing" innovation is only possible when the entire ecosystem is considered. When environmental variables change faster than products or services can adapt, disruptive innovation is required to keep pace. This has many parallels with natural ecosystems where species that cannot keep up with changes to the environment will struggle or become extinct. In this case the environment is the city, the environmental pressures are pollution and congestion, the product is the car and the product ecosystem is comprised of roads, bridges, traffic lights, legislation, refuelling facilities, etc. Each one of these components is the responsibility of a different organisation and so any change that affects the whole ecosystem requires a transdisciplinary approach. As a simple example, cars that communicate wirelessly with traffic lights are only of value if wireless-enabled traffic lights exist and vice versa. Cars that drive themselves are technically possible but legislation in most places doesn't allow their use. According to innovation theory, incremental innovation tends to chase ever diminishing returns and becomes increasingly unable to tackle the "big issues". Eventually "game changing" disruptive innovation comes along and solves the "big issues" and/or provides new opportunities. Seen through this lens, the environmental pressures of urban traffic congestion and pollution are the "big issues". It can be argued that the design of cars and the other components of the product ecosystem follow an incremental innovation approach. That is why the "big issues" remain unresolved. This paper explores the problems of pollution and congestion in urban environments from a product ecosystem perspective. From this a strategy will be proposed for a transdisciplinary approach to develop and implement solutions.

Keywords: product ecosystems, transport, wicked problems, Design Thinking, congestion, USV, micro car.

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1 Introduction

Over the 20th century there have been few, if any, products that have had such a profound influence on our way of life as the car. Cars have allowed our cities to grow, they give us the freedom to live, work, shop and spend our leisure time where we choose. But this love affair with the car has caused problems. The main ones being pollution and congestion.

The problems of traffic congestion have been with us for a long time and are getting worse. Projected population increase and vehicle ownership rates will only compound the problem. However despite vast sums of money being spent on the problem, congestion stubbornly remains.

"We can't solve problems by using the same level of thinking we used when we created them" is a quote often ascribed to Albert Einstein. Certainly, the problems of traffic congestion remain stubbornly resistant to the approaches tried so far. Therefore this paper puts forward the conjecture that it is time to look at the problem from a different perspective.

This paper proposes a potential method for addressing the problems of traffic congestion. It draws on a theoretical framework that comes from a variety of disciplines including natural sciences, sociology and design.

1.1 The size of the problem

100 years ago, only 13% of the world's 1.6 billion people lived in cities: around 200 million people. The world population is now over 7 Billion, 50% of whom now live in cities giving us an urban population of around 3.5 Billion. In approximately the same timeframe the number of cars has increased exponentially from a few thousand to the point that there are now an estimated 1 billion cars worldwide. This gives an average of about 138 people per 1000 cars worldwide. There are of course countries with higher rates of car ownership, Australia for example has one of the highest rates of car ownership at 750 cars per 1000 people [1]. Australia is also one of the most urbanised countries worldwide with nearly 90% of the population living in urban areas. [2]. In addition, Australia has relatively low density cities making them difficult to service with public transport. This combination of factors mean that cities like Sydney have some of the worst traffic congestion in the world [3].

These figures have been included to illustrate the enormous change from rural to urban populations as well as the rise of the car. As the concentration of cars in an urban environment is an underlying cause of traffic congestion, it is reasonable to expect that traffic congestion will also increase if urban growth patterns continue. Traffic congestion can be very costly in both financial and social ways, In Australia for example the financial cost of congestion due to lost production has been estimated to be from $9 Billion in 2005 AUD pa. [4] to $25 Billion in 2011 [5]. The social cost of time wasted in traffic is harder to quantity but nonetheless significant.

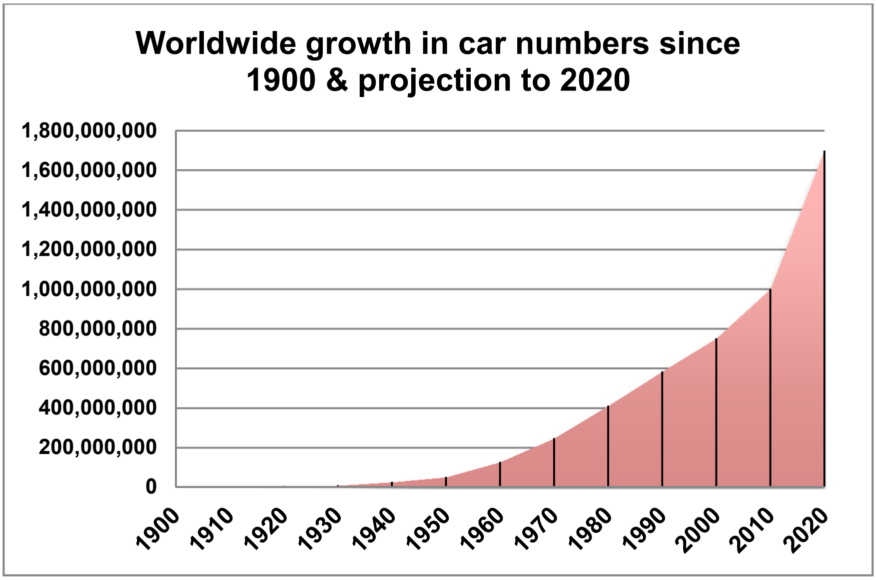

Figure 1: Worldwide growth in car numbers since 1900 including projections to 2020. Various sources [6–8].

Traffic congestion is a growing problem in many if not most urban areas. The problem is being compounded by many factors including population growth, increasing levels of urbanisation, economic growth and changing lifestyles. The imperative to find solutions to the problem of congestion is driven by factors such as atmospheric carbon emissions, urban air quality as well as the lost opportunity cost of time spent in traffic, both economic and social. These problems are particularly difficult to address. Many approaches have been tried, many of which involve attempting to persuade people to not drive, for example use public transport, cycle or walk instead. The success of these approaches tends to be inversely proportional to the density of the city. This is because in low density cities such as those found in Australia public transport is less effective. Road infrastructure is the main approach taken with Australia with road spending $24 Billion pa. [9].

"Transportation is not a closed, self-contained system; rather, it is tightly intertwined with other systems" [10] and yet most attempts to improve traffic congestion tend to look at isolated parts of the system and not as a whole.

There are many that believe that the time has come to look carefully at the whole road network as well as the vehicles on the roads to design a system that minimises the problems [10, 11].

2 Theoretical framework

This paper draws on a variety of theories that can be used to help frame the problem as well as develop an approach to address the problem.

2.1 Wicked problems

Traffic congestion is an example of a wicked problem. The concept of a "wicked problem" first described by Rittel and Webber [12] refers to social problems that are complex and difficult, if not impossible to solve. Wicked problems rarely have a single definitive solution and typically span many different disciplines. It is more likely that outcomes can be described as "better" or "worse" rather than "solved". Often, due to the complex interdependencies involved and the multidisciplinary nature, solutions may cause other problems often for other disciplines. For example, crime is a wicked problem that can only be improved and will never be solved. Attempts to address crime may include increased police presence, which is addressing the symptom rather than the cause. The cause of crime probably stems from deep-seated social problems. These social problems are complex, wicked problems in their own right. Wicked problems are very often problems that are multidisciplinary in nature in which case they can only be addressed effectively by using a transdisciplinary approach.

Although wicked problems by definition cannot be solved, they can be addressed and a better position found. Design problems are normally always wicked problems in that there is no single solution and the description of the problem is likely to be ambiguous and contradictory. A design solution is never a perfect solution but can only be considered as better or worse. Design problems typically have many criteria, some of which may contradict others. Designers therefore tend to be comfortable working with ambiguity and chaos which is why Design Thinking is an ideal approach for tackling wicked problems.

The scientific approach to solving problems usually involves a clear problem definition including an empirical method for measuring and defining both the problem and the solution. This approach is unsuitable for wicked problems because the problem as well as the solution are difficult, if not impossible, to define or measure. Scientific thinking tends to reductionist in its approach. That is, by reducing the problem down to its smallest component it becomes easier to define. Wicked problems are ones that do not respond to a reductionist approach and require a holistic approach. For this reason, the process of "Design Thinking" is increasingly being seen as the most effective way to tackle wicked problems [13].

2.2 Design Thinking

Design Thinking is a process for addressing problems based on the way that designers tackle design problems. It is not a defined methodology but rather an approach that designers use. This approach is well suited to tackling ill-defined problems that contain multiple conflicting criteria. The approach is typically holistic and expansive as opposed to reductive. Designers will typically explore and expand on many potential solutions to a problem before selecting the most promising direction and resolving it. This is distinct from a scientific approach, which is more suitable for “tame” problems [14].

Design Thinking is naturally used in most design disciplines but is increasingly used outside those disciplines such as business and soc. According to Plattner *et al.* the basic structure of Design Thinking can be described as “Understand, Improve, Apply” [15].

Wicked problems are complex and typically transcend discipline boundaries. If Design Thinking is to be used to tackle wicked problems, a transdisciplinary approach is needed where each discipline uses Design Thinking to contribute to the solution.

2.3 Product Ecosystem Theory

Product Ecosystem Theory is an emerging theory that proposes that successive iterations of consumer products will exhibit similar evolutionary patterns as those found in biological ecosystems [16–18]. Evolutionary theories such as phyletic gradualism and punctuated equilibrium can be observed not just in biological evolution but also in product evolution. Phyletic gradualism describes the gradual evolutionary morphology changes in species over time. In contrast, punctuated equilibrium describes periods of stasis or phyletic gradualism with occasional and rare rapid changes or branches in species [19]. In biology, changes in morphology are driven by environmental pressures or opportunities. Again the same patterns can be observed in product lines. Therefore by understanding the environmental pressures and opportunities that affect products we can gain a better understanding of what sort of environment a product requires to flourish. More importantly it allows us to see what environmental variables can be modified to make a product more or less viable.

The evolution of the car over the last 100 years clearly follows the pattern of phyletic gradualism. That is, all the major components and layout of contemporary car can be observed in cars of 100 years ago. For example, steering wheel, seating arrangements, mirrors, headlights etc. are all in the same position and function in the same basic way. This is not to say that cars have not changed, rather a gradual refinement of the car has taken place. This refinement is demonstrated in the way that engines have become more efficient, and cars have far greater level of comfort that their predecessors had. And this is consistent with phyletic gradualism.

In nature, punctuated equilibrium describes an evolutionary process marked by periods of relatively little change punctuated by new species rapidly evolving and either displacing the previous species or coexisting with them. This pattern can be seen in product. For example, the development of the aeroplane has followed a pattern of periods of stability followed by Rapid change. For example a military aeroplane of 100 years ago was typically an open cockpit biplane that bears little resemblance to a modern supersonic jet fighter. The Hindenburg shares even less with the Concorde despite being separated by only 32 years.

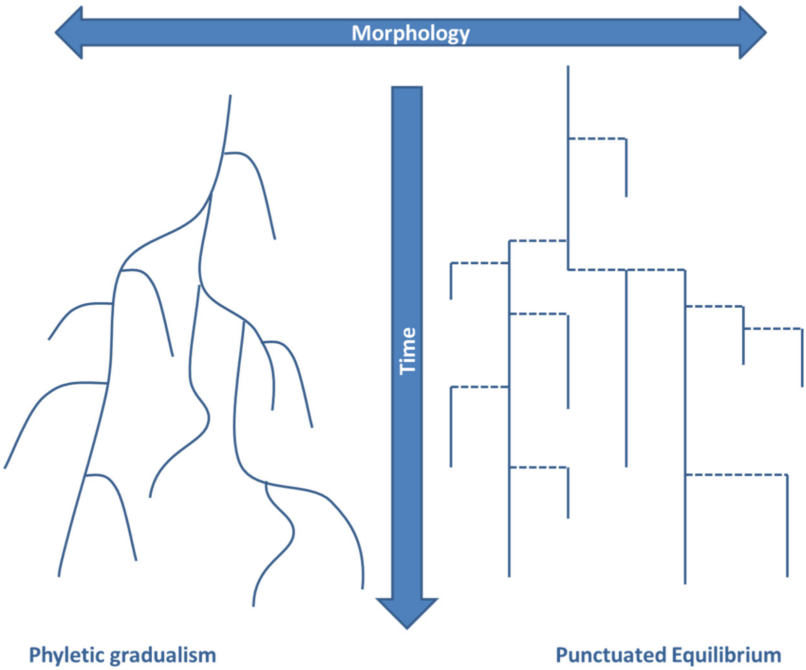

Figure 2: Graphical comparison of phyletic gradualism and punctuated equilibrium. Based on [20].

Species within a natural ecosystem and products within a product ecosystem are both interdependent on their environment, whether it is the natural environment or the product environment. The car's environment has also evolved over the last 100 years in ways that support the evolution of the car. For example the network of roads has expanded and improved in quality allowing car passengers to travel at higher speeds and in greater comfort than previously. Traffic lights, road signs, street lights, speeding cameras, tarmac and multi-story car parks have all been developed to support the car through the process of phyletic gradualism. As well as the less tangible items such as road rules, design standards, licensing, policing and so on. Another group are the support services such as fuel stations, crash repairs, mechanical repairs, tyre, battery and exhaust mechanics. These are just some of the things that form the car ecosystem. Without this supporting ecosystem the car would have far less value and would be far less viable.

This has strong parallels with natural ecosystems. All species rely on their environment. If the right combination of food, water, shelter, sun, shade etc. is not present the species must either evolve or decline.

By understanding the interdependencies of the car ecosystem and modifying the environment accordingly we have control over the viability of the car. For the car to undergo a change consistent with punctuated gradualism, the whole car ecosystem must support this new evolutionary branch.

3 Finding solutions to congestion

3.1 Existing approaches

Other than approaches that aim to reduce car usage such as public transport and cycling, the main approach to reduce traffic congestion is to improve road infrastructure. Vehicle throughput is the typical metric of improving road infrastructure (in the context of traffic congestion). A better metric, which is more difficult to measure and therefore less often used, is people throughput.

The throughput of roads can be improved by increasing either the capacity of roads or the efficiency of them. Increasing capacity has natural, finite constraints; the available corridor width being the main one. Expanding beyond available corridors requires approaches such as elevated roadway, tunnels and compulsory land acquisition and demolition. These approaches tend to be very costly both socially as well as economically. Attempts to increase efficiency include measures such as bus lanes and High Occupancy Vehicle (HOV) lanes.

3.2 Currently proposed approaches

There are those that argue the car in its present form needs to be reinvented [11]. In the context of Product Ecosystem Theory this would mean that the car has reached a fork in its evolutionary line and that the forces of punctuated equilibrium need to take place. This typically takes place when the environment is no longer suitable or when new opportunities arise. In this case congestion is an environmental pressure that makes car use less viable. Fossil fuel costs, availability and security, coupled with CO_2 emissions and air quality are all environmental issues that are increasingly making cars in their present form less viable. Even the way in which we use are cars is in many cases no longer compatible with the types of vehicles commonly used. For example, in many urban areas, single occupant trips make up as much as 70% of all car trips when most cars have the capacity of 4 or more adults [5]. These are some of the environmental pressures that can "push" evolution. There are also environmental opportunities that can "pull" evolution. These are often technology opportunities such as improvements in batteries that can make Battery Electric Vehicles more viable.

Mitchell *et al.* [11] propose a design solution comprised of small, electric folding cars, a type of Ultra Small Vehicles (USV). These vehicles are currently in preproduction in Spain. The design philosophy behind these cars is quite simple. Smaller vehicles use less space both on the road and when parked. But Mitchel argues that it is not just the size of the car but that electronics that Collision avoidance and the ability to platoon also allow a more efficient use of the road space [11].

This is not the only attempt to find a design-driven approach to reinventing the car. Most of the major auto manufacturers have at least concept cars that are small, electric cars with one or two seats. Some manufacturers such as Renault have been producing this class of vehicle (the Twizy) for a number of years. Whilst the Twizy has been successful compared to other electric cars, overall numbers are quite low. One possible reason for this is that whilst USVs potentially reduce congestion in large numbers, individually they do very little and any benefits they do bring are shared amongst all road users. At the same time the disadvantages with USVs (e.g. lack of carrying capacity) are born only by the USV driver. To illustrate the point, reviews of the Twizy often make comments like this

> *"The Twizy is so tiny that three could probably fit into a standard parking bay, but that's not allowed either: each Twizy incurs a normal car's charge"* [21].

This can be explained by Product Ecosystem Theory; because the road ecosystem is designed for the conventional car is it not optimised for the USV, therefore the potential benefits are unlikely to be realised. To make the USV truly viable the ecosystem needs to be reinvented along with the car.

Figure 3: Renault Twizy [22].

According to Design Thinking principles we should not start with the intention to design a better car, we should start with a broader view and look at redesigning an entire system that reduces congestion and pollution.

3.3 Future solutions

Many city streets are older than 100 years, even in relatively "young" countries like Australia. This means the car did not exist when these streets were laid out and therefore not designed for cars: certainly not in current numbers. As previously mentioned, urban populations and number of cars were a fraction of what they are now. And yet the overall form and function of cars has hardly changed. There is a strong argument that supports the conjecture that it is time to take a new look at the way we travel around our urban environments. Whether that is to reinvent the automobile as Mitchell *et al.* [11] suggest or by employing the "new mobility" approach that Goldman and Gorham [10] describe. Either way this is an opportunity to develop a transport system that will enhance rather than degrade the amenity of our cities.

It is beyond the scope of this paper to suggest a solution; however a methodology can be suggested that will allow an approach to be developed. This methodology is a seven step process which based on Design Thinking.

1. The first consideration is that a single discipline cannot tackle this problem alone. The USV is an example of a design solution that needs the support of other disciplines such as those involved with infrastructure and legislation to make it viable. All stakeholders should be involved with subject area specialists from all key disciplines. This is consistent with the way that Design Thinking is used to address wicked problems [13].

2. The second step will be to develop a set of design criteria. These criteria are to be used to evaluate the design proposals. Due to the complexity of the problem, the list of criteria can be expected to be quite large and include a range of both tangible and intangible criteria. This approach is consistent with Design Thinking and is typical approach that a designer may use; the only thing unusual is the size of the project.

3. The third step will be the ideation step. Idea generation techniques such as brainstorming should be used to generate as many ideas as possible. These will then be recorded in sketch form.

4. The fourth step is the filtering step to reduce the ideas to a few of the most promising ones.

5. The fifth step is the resolution stage where the best ideas are refined to a higher level of detail than the initial concepts. These ideas would then be compared with the design criteria to select the best idea.

6. The sixth step is the implementation planning stage where each discipline will set out what would be required for implementation from their discipline's perspective.

7. The final stage will be the documentation stage where the plan will able to be presented in a way that can be easily understood by someone unfamiliar with the project.

Although the process described above and shown in Figure 4 is a linear process, this is unlikely to be the case. Design is often an iterative process where knowledge learned in one step is fed back into a previous step and part of the process repeated, looking more like. For example, something may be discovered at the resolution stage that can refine the criteria, requiring a repeat of the ideation stage. This is a normal part of the design process. Whilst designers may be familiar with this process, it is likely that other disciplines are less familiar and perhaps less comfortable with this process. Careful management of the team may be required.

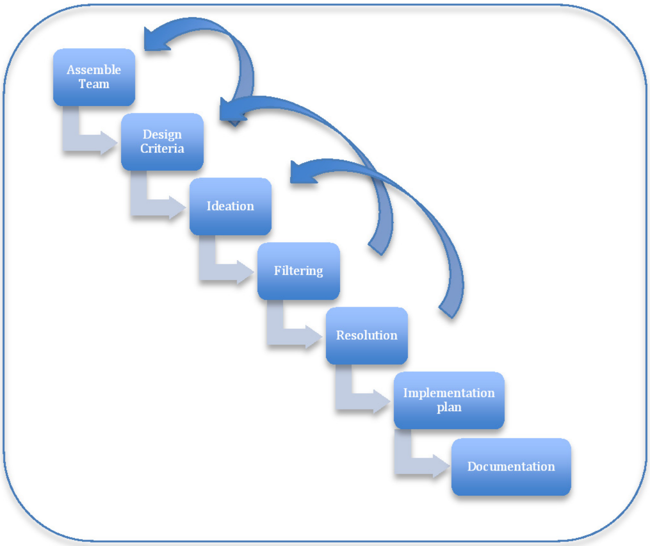

Figure 4: Proposed methodology for generating an approach to reducing congestion.

4 Conclusions

The problem of traffic congestion remains stubbornly intractable. Car design by itself is unable to solve it. Infrastructure building hardly seems to make a dent. It now seems the time has come to take a holistic view that will redesign urban mobility and place it in a more sustainable position. Product Ecosystem Theory provides a framework that will help conceptualise the approach. And Design Thinking is an ideal method for tackling wicked problems of this sort.

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