Science, Technology, and Society Research Paper

Social and Technical Efficacy of Interconnected Multimodal Transport: An Integrated Commute

(STS Research Paper)

Presented to the Faculty of the School of Engineering and Applied Science University of Virginia – Charlottesville, VA

In Fulfillment of the Requirements for the Degree Bachelor of Science, School of Engineering

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Spring, 2020

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Introduction

This paper will examine the efficacy of fully connected multimodal transport in cities through the potential evolution of related social and technical factors using the STS framework Social Construction of Technology (SCOT), and through research connected with the technical project , "Investigating the Feasibility of a Fully Connected Unsignalized Intersection." The technical project aims to determine the feasibility of an intersection driven by the connectivity between autonomous vehicles and pedestrians' personal devices. Based upon SCOT, this paper seeks to determine which social factors, if any at all, must adapt and advance to allow the continued technological development of interconnected multimodal transport systems.

Note: This investigation will be made through the lens of the situation to occur in the United States of America, given its unique federalist governmental system and status as a heavily developed nation. While other, smaller countries may have parliamentary governmental systems which make central decisions regarding transport for their own country (many in Europe are like this) the United States, due to scale and historical context, must outsource its development to more localized governments rather than a central one. Hence, discussion of transportation development may be quite different between differing governmental and geographical areas and systems so choosing the United States' unique system will allow for a more focused look at the issue.

STS Framework: Social Construction of Technology

Social Construction of Technology (SCOT) is a theory within the field of science and technology studies which argues that human action and development shapes technological change. SCOT was developed as a response to technological determinism, a theory functionally opposite to SCOT, and is known sometimes as technological constructivism. The four key tenets of SCOT, through which the development of Interconnected Multimodal Transit (IMT) will be investigated, are as follows: interpretive flexibility, relevant social groups, closure and stabilization, and wider context.

Interpretive flexibility in SCOT refers to the fact that each technological artifact and development may have vastly different meanings, interpretations, or repercussions for various social groups.

The relevant social group, the second tenet of SCOT, focuses on on the groups which differ through their alternative interpretations of the technology. Tied in with interpretive flexibility, it is necessary to examine all stakeholders in technological development to determine their goals and intentions for the technology and its use.

The third primary tenet of SCOT is closure and stabilization, the process in which controversies and conflict arise when there are different interpretations of the same artifact. This tenet would focus on how relevant social groups would interact in the development phase due to their different interpretations.

The fourth and final tenet of SCOT is wider context, necessitating investigation of the broader global order which would push societies towards these technological advancements. It is important to understand the context and reasoning behind different groups' interpretations of new technology before examining their interactions between each other in the development phase of such new technologies.

Link between SCOT and Multimodal Transit

In contrast to technological determinism, SCOT recognizes that both social and technical forces interact to shape the development of technology. In this paper, I argue that two main factors – city growth and, in turn, pollution concerns – push transit development towards a more interconnected multimodal system in large urban areas. I will first outline my concept of current multimodal transit and discuss the factors that necessitate its future development, linking it to the four main tenets of SCOT: interpretive flexibility, relevant social groups, closure and stabilization, and wider context.

Multimodal Transport: what is it?

Multimodal transport refers to "connectivity of more than one mode to a line haul in an urban area" (Kumar, Parida, Swami). Cities, relying historically on vehicle travel, now may rely on buses, subway systems, and bicycles more so than before due to heightened population density and condensed roadways. As cities grow, and existing infrastructure fails to support transportation demand, new transportation modes organically form. What if a city which utilizes ridesharing, scooters, buses, subways, and bicycles, all provided from different entities public and private, employed a central planning system which connected all of these parts into one? This paper seeks to understand the conditions in which transportation development drives *towards* this concept, not necessarily *to* it, with a focus on the efficiency of the networks themselves and the benefits increased efficiency could bring to society. The potential benefits and development of fully interconnected multimodal transport will be investigated through examining the impending effects of population growth and pollution.

City Growth and Efficiency Concerns

More than half the world's population lives in cities, and projections indicate that urban areas will account for 60% of the global population by 2040 (Goetz, 2019). As cities continue to expand, their urban transportation systems atrophy immensely. Studying over 200 cities from 38 countries, it was found that over half of them registered 100 hours lost in congestion per driver per year; in the United States congestion costs in 2018 were estimated to be $87 Billion (Goetz, 2019). From an economic perspective, "the primary characteristics governing the qualitative interaction potential of metropolitans or large cities are the land use and transportation system taken in combination," (Kumar, Parida, Swami, 2013) meaning the economic prosperity of a metropolitan area, to an extent, relies on the potential of its transportation system. Hence, as cities grow the efficiency of their urban transportation system – the roadways and public transit systems that their citizens rely on – is paramount.

How may the problem of inefficient urban traffic be rectified? Making sure that *public transit systems* are as efficient as possible. Multimodal networks are the most efficient, as demand is spread across "nodes" (biking, buses, rideshare, etc.) reducing reliance on any one method of transport. *Fully integrated* multimodal transit systems would find a way to connect all such "nodes" together into one platform, allowing for centralized trip planning, automation, and optimized routes for the user. As cities grow, their current designs fail to keep up with the increase in vehicle traffic – vehicle traffic further increases pollution as well, harming the collective quality of life and adding further burden to the global climate crisis.

Multimodal Transit and Pollution Concerns

As cities continue to grow, and populations continue to expand, cities will be forced to deal both with efficiency and pollution concerns. Increasing transportation efficiency – and thus, the development of multimodal transport systems – lies in the middle of the solution set to this issue. The transportation sector is responsible for roughly 70% of American petroleum use, which greatly increase harmful greenhouse gas emissions, and the 'movement of people' (as opposed to goods) makes up 70% of the transportation sector's total energy use and greenhouse gas emissions. Automobiles and light trucks, combined with passenger air travel, account for almost *99%* of passenger-miles, and those three modes cumulatively make up roughly 92% of transportation energy use (National Research Council, 2010). Following, according to the National Research Council two of the four main ways to reduce transportation-related greenhouse gas emissions (and, thus, pollution) are to **Reduce the total volume of transportation activity** and **Shift transportation activity to modes that emit fewer GHGs.** Multimodal transport, especially a centrally sourced transportation system, could show great promise in supporting those two. Currently, commuting only accounts for roughly a quarter of passenger trips, so carpooling strategies have limited potential; however, new connected ridesharing technologies and dynamic routing with more efficient vehicles may be used to disincentivize emissions-laden personal vehicle use in a multimodal system.

Regarding the second step, to shift transportation modes, the most widely discussed option with regards to the movement of people is "inducing people to substitute some of their driving with public transportation service, bicycling, and walking," which are key tenets of multimodal transportation systems. In a report by the U.S. Federal Transit Administration it was found that transportation accounts for 29% of the United States' greenhouse gas emissions, with personal vehicle transport making up 57% of that 29% (public transit makes up 10%). In most places currently, load factors are, however, not high enough to make public transit services more energy efficient. Deviating from the current fixed route system which relies on passenger demand in specific areas, and moving towards a dynamic multimodal system which automatically plans the most efficient routes, may allow public transit to become the greenhouse gas, and thus pollution, reducer it has the potential to be. Thus, a more efficient, smarter, and cost-effective public transit system may prove beneficial in the fight against city pollution.

Analysis of Multimodal Transit Efficacy Through SCOT

In this section I will first outline present day multimodal transit systems in their current form, leading into a description of presently mentioned concepts for interconnected multimodal transit in smart cities both as proposed and conceptually, based upon the main drivers (city growth and pollution) mentioned previously. I will describe the potential for such systems to go through the four main tenets of SCOT: interpretive flexibility, relevant social groups and stakeholders, closure and stabilization, and wider context. Finally, I will present my prediction for what such systems will generally develop into given the current state of affairs with such systems and the potential for the aforementioned drivers to drive the systems' development.

Multimodal Transport: State of Affairs and Main Concepts

The UN has laid out three "building blocks" of multimodal transit integration: infrastructure and operational integration, information integration, and fare integration. Infrastructure and Operation Integration involves different transport modes connected physically as well as operationally, such as having a transfer station involving both buses and trains; information integration involved having a central user interface for the transit system, like an app; fare integration involves having a central payment system for all transit modes, like having a "SmarTrip" card in Washington, D.C. which allows for payment both on city buses and trains. Several cities have already implemented relatively integrated multimodal systems, such as London, Paris, New York, and Singapore which all have multimodal infrastructure, centralized payment methods, and centralized status websites or apps to show either transit timing or traffic information. These developments have been made possible recently partly due to significant technological advancement with new multimodal trip planning applications, traffic monitoring, and real-time information on mobile devices as well as the integration of new integrated payment systems which take advantage of contactless cards – 250 cities are currently utilizing this technology (SmartCitiesDive). Without technologies such as near field communication, which came to prominence in 2004 and allows for contactless payment (Tardi, 2020) and large-scale cellular service, these developments in multimodal transit would not have happened.

Future developments in multimodal transit systems in developed countries will focus on the integration of shared-mobility services such as car and bike sharing with mass transit, and the advancement of current and newer technologies such as mobile payments (Apple/Google Pay, etc.) for multimodal trips. Developing economies, less advanced in the deployment of integrated transit, will need to ensure that cities are able to develop strong and unified transport authorities as well as the political will to move forward with integration. These technological and social forces, in the developing and developed world, will drive the development of integrated multimodal transit. I shall now describe the potential for the technology's development through an outline rooted in the tenets of SCOT, grouping interpretive flexibility and relevant social groups due to their interconnected nature.

Integrated Multimodal Transit – Interpretive Flexibility and Relevant Social Groups

Interpretive Flexibility in SCOT refers to the concept that different technologies and technological development may have different definitions or meaning to differing relevant social groups. In the case of interconnected multimodal transit, this could mean the system being interpreted as a cheap and easy way to commute for the general worker, a way to control the flow of people from the perspective of a strong city or central government, or a potential cash cow for private industry. The main stakeholders (relevant social groups) to be focused on in the analysis of the development of an interconnected multimodal transport system are state, local, and federal governments, private developers of transportation technology, environmentalists, and city transportation workers, residents of the surrounding affected area, and commuters (generalized as *constituents)*. The overarching structures themselves can be considered actors, making the individuals who make them up (without separation) less significant as they are acting in the interest of the structure itself.

State, Local, and Federal Government

Governments will be on the hook most significantly for remedying the city growth and pollution issues presented earlier. City governments, faced with vast growth, will need to find ways to prevent overcrowded transportation systems, or risk disruption of supply chains and citizen unrest which may arise alongside them. Higher levels of government will need to work to develop climate change standards to fit with the global order, and in turn city and local governments will need to develop new transportation systems with such standards in mind.

Private Industry

Private Industry, working in tandem with government, will view new transportation technology and plans as opportunity for new development, research, and contracts. With the necessity of new and more efficient transportation solutions due to city growth and climate change, private transportation development will be booming – boosted by a breadth of government contracts and increased competition. These new developments will be seen by large planning and engineering corporations as both a chance for increasing their profit margin and to improve their public image by developing technologies aimed at improving society.

Environmentalists

"Environmentalists," in the context of this paper, will refer to those in the scientific community concerned with infrastructure's effect on its surrounding natural environment. To environmentalists, an interconnected multimodal transit system may be viewed as a way to alleviate the effects of city pollution – a net benefit for cities' surrounding environments.

Constituents

Constituents, generalized to refer to those who vote (depending on their nation's system) either for passage of issues themselves or for representatives to represent their beliefs in a representative system, will generally view any new developments as a large tax burden. Constituencies will have their own nuanced view depending on their relation to the potential new transportation system. Constituents will frame their voting habits relative to transportation issues through their relation to the system – are they commuters? Residents disgruntled with noise pollution? Workers in the industry? Their views may also be swayed depending on political leaning or framing by their elected officials – a much larger, more nuanced conversation than which can be discussed in the framing of this paper.

Interconnected Multimodal Transport – Closure and Stabilization

Closure and Stabilization – the third tenet of SCOT – refers to the process by which the relevant social groups, with their respective interpretations of the artifact at hands, engage and conflict with each other over time in order to refine the artifact into its final form. In this case, we have the governments, contracted by their constituents to provide necessary and efficient services at the lowest possible price, facing off against the private industry – focused primarily on their own profits. The examples presented in this analysis are relatively general – the issues and compromises at hand would happen under any new transportation development project for the most part, however it is important to emphasize the fact that these issues would arise in a period of intense time pressure for the new developments given the projected city growth and climate emergency.

Governments vs. Private Industry – the 1st major struggle

Although a strong central government may have the financial resources to undertake a new transportation development, for most countries it will make more sense to outsource development (to a degree) to localities who better understand their respective areas. Cities themselves, with their prior development, constituency, and needs, will need to be the leading players driving their own transportation system development. Certain localities, for example, have enough in-house experience with bicycle development that they will not need to hire outside assistance, but others will. Within this localized process, cities will need to negotiate with whichever firms are available to them in order to get the most cost-effective solution. For those in more populated areas, this will be theoretically easier – a larger pool of companies, more competition, and lower price – but for those in less populated areas, cities and localities may have limited choices leading them to pay more than the optimal amount. This leads to the first major compromise, in which certain localities will have to accept higher prices for labor in the face of reduced competition and companies which are aiming to make the most money as possible. Localities will need to make these decisions in the face of constituent and commuter preferences.

Governments and Corporations vs. Constituents – the 2nd and 3rd major struggles

The second major compromise arrives at the intersection of the previous conflict, between corporations and governments, and those who the governments answer to – the individual; the constituent. Government officials, and in turn the policy directives they develop and implement, are brought to power – usually – by public election in each locality. In the

United States, this leads to accountability at local (city), state, and federal levels as to how tax dollars are being spent, officials are best putting forth the interests of those who elected them, and how officials are best prioritizing what they fight for in the power structures they work in. Hence, internal conflicts arise in which government workers (and in some cases, the structures themselves) deviate in opinion from those who elected them. The more people the representative answers to, the more amplified this dilemma becomes. The problem becomes more significant with the realization that business and other interests play a significant role in elections at all levels – choosing one company over another to develop a new bicycle trail in order to fit with a multimodal transit initiative may drive other competing businesses, and jobs, out of town.

A triangular series of compromises

The dynamic can now be understood to be a triangular conflict between private companies, government, and constituents: constituents demand efficient allocation of their tax dollars, and a working public transit system; government officials must to an extent sacrifice their own opinion in the face of potential voter outcry, while abiding by rules and regulations and whichever policies have been mandated; private companies must attempt to make the most money possible while staying competitive, and juggle research costs to stay ahead of the curve; all the while, the constituents and companies (through donations and initiatives) who help to elect government officials may pressure such officials to work certain ways.

Scientists – on the outside looking in

Differing from governments, constituents, and private industry, who all take their own action to press change, scientists' way of acting towards shaping new developments lie in their capacity to advise those around them or sway public opinion, rather than spending money or voting. The American Centers for Disease Control (CDC), for example, cannot truly implement policy and must rely on the executive to carry out their demands. If a government is most interested in fiscal and temporal efficiency, they may choose development paths and technologies which may not align with environmental recommendations. Giving environmentalists a significant advisory role over policy may lead to significant project delays, increased cost, and a lack of efficiency. Hence, a final outside conflict arises between the scientific community, prioritizing environmental safety on a global and local scale, and government and private actors who require the best possible work at the lowest possible cost of time and money.

Interconnected Multimodal Transport: Wider Context

The wider context involved in the development of interconnected multimodal transit systems stems primarily from the aforementioned city growth and pollution concerns. Major cities are growing rapidly, and in turn vehicle traffic is growing with them. Congested highways and local roads both increases commute time and prevents efficient trade through restricting travel such as ground shipment and deliveries – remedying this dilemma can be achieved through either reducing road congestion or finding alternate modes of shipment and delivery, both elements of a truly interconnected multimodal transport system. Developing in tandem with population booms is the increase in city pollution, which gets worse as time goes on. More people require more resources, which require energy, industry, and logistics to develop. Given current technology, these elements will continue to be inefficient environmentally, temporally, and financially, necessitating new methods of logistics and industry. Such developments, although widespread, would be implemented at the local level as mentioned previously.

Potential Counterarguments and Objections

<u>There are many other ways to attempt to solve pollution or city congestion, such as switching to cleaner energy sources and developing rural areas. Why focus on an added degree of interconnectedness in public transit?</u>

It is important to realize and accept that no singular solution can fix these major issues. Cleaner energy sources are but one of the many necessary methods available to remedy pollution damage and incentivizing people to move out of cities will temporarily fix crowding problems, but develop them further in the long term. The benefit of truly efficient, interconnected multimodal transit is that it presents another benefit for *both* problems – playing a small part in each issue but ultimately helping in the long run. These problems will exist, so instead of outright waiting for cure-all solutions it would be in the best interest of communities to deal with them as best as possible.

<u>In most major cities, public transit is run by a central organization. How is what you are referring to different?</u>

What I am referring to as interconnected multimodal transit should not be understood to be a completely new phenomenon, but a build upon current frameworks that must be acknowledged presently. Future systems will most likely be functionally similar to the average person, however will utilize far more advance transportation technology and infrastructure. If mobility as a service (MaaS), a subscription or taxpayer funded service which provides users with rides on demand from autonomous vehicles, becomes the primary medium of commuting for a city's residents, such a city would want to try and integrate it with the surrounding area's transportation system as best as possible. With large scale ridership, it would not be efficient to put everyone in cars, even if the cars drive themselves – this would mean promoting bus, eVTOL, and subway ridership by the central planners of city transportation departments. In order for this to be done, *all* transit methods would need to be combined on a single platform, as not to leave any out – even if they are manufactured or maintained by different companies. Hence, we have a necessity for fully interconnected multimodal transit.

Will this really become a *pressing* issue? Considering you are writing about it, and have basic information regarding the technology's development, work must already have been done to at least start research on the concept. Who's to say that governments will not do the right thing and work on an appropriate timeline for its integration?

Similar to how environmentalists show their power in advisory roles, not explicit ones, governmental policy research does not imply governmental policy implementation. Governmental and private agencies conduct research on a wide range of topics without taking action on them – representatives in the United States regularly mention vast amounts of research which has been done on gun violence, however rarely present legislation to remedy such gun violence. If issues that exist simultaneously to a transportation crisis are presented as more prescient to the constituency by their representatives, the public may press for those issues to be addressed before the transportation issues are addressed. Hence, there is a string of inefficiencies in the three way conflict mentioned earlier, in which – circumstantially – those in positions of power may not truly understand the most important issues to tackle and may leave time sensitive issues in the back seat for too long.

<u>Private industry will most likely be the ones developing the infrastructure for these systems, and it is private industry which – up to this point – has primarily lead the research initiatives. In this case, why are you so sure that governments will be the driving force in their implementation?</u>

State and local governments, in the United States at least, oversee their respective transportation authorities and are contracted inherently by their citizens to provide for certain safe, equitable, and cost effective services such as public transportation. Existing transportation systems are built and maintained primarily by transportation authorities. Because of this, as new transportation infrastructure is developed it will have to be integrated with the current system, which can only occur if they share the same platform – necessitating oversight from the same transportation authorities. Hence, although private industry will be the ones physically contracted to create new infrastructure, they will be contracted by governmental agencies which will demand oversight and for the private industry to follow predetermined rules and regulations.

Conclusion

As cities continue to grow, transportation technology begins to develop, and public interest becomes more and more intent on remedying the global climate crisis, constituents, governments, and private interest will push each other towards the development of fully interconnected multimodal transit systems. Such systems will be developed through a complex interaction between the aforementioned social forces, creating situations in which compromises must be made by each actor in order to shape the systems' final form. =Compromises will differ by locality, value systems, and current states of being in such localities, all leading to slightly different systems but with similar underlying characteristics and technologies. Social construction (SCOT) will drive the development of these interconnected systems and will face countless challenges due to constant clashes between the differing social actors. Years from now, when these systems are implemented globally, they have the chance to benefit societies greatly by reducing commuting time and emissions; these systems also have the potential to be incredibly poorly implemented and exacerbate the very problems they were created to fix.

Resources

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