

Technology Transfer (T2) Plan

Center for Connected Multimodal Mobility (C²M²)



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FAST Act research priority area: **Improving Mobility of People and Goods**

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1. INTRODUCTION

Our vision for the Center for Connected Multimodal Mobility (C²M²), a Tier 1 USDOT University Transportation Center, is to become a globally recognized multimodal mobility innovation center for moving people and goods, specializing in connectivity, data analytics and automation. To achieve this vision, our multidisciplinary research team is drawn from five leading higher education and research institutions in the state of South Carolina:

- Clemson University (CU), the lead institution
- The University of South Carolina (USC)
- The Citadel
- South Carolina State University (SCSU)
- Benedict College (BC)

All five schools have a strong record of successful collaborations with the federal and state departments of transportation (particularly the South Carolina DOT), other government agencies, academia, and private industry partners. We are working together to create and develop new initiatives, innovations, and inventions by combining our complementary research strengths, our education and workforce development activities, our commitment to diversity, and our expertise in emerging communication and computing technologies. Our overall goals are to:

- Advance the frontiers of knowledge on myriad aspects of transportation, promoting mobility, safety, cost-effectiveness, sustainability, and equity
- Use this knowledge to develop technology and ideas that will be rapidly implemented to improve the transportation system
- Maximize the impact of the taxpayer dollars supporting our research by disseminating our findings as broadly as possible to government agencies, private sector firms, industry organizations, and the current and future transportation workforce
- Increase the visibility and capabilities of our partner institutions

Our technology transfer initiatives are at the core of our Center's vision. C²M² sponsors, conducts, and disseminates research that results in using data, connectivity, and automation to promote access to opportunities and innovations. To accomplish this, we have developed, and continue to develop, numerous strategies that will improve transportation system performance, for example by:

- Maximizing existing transportation infrastructure capacity via Vehicle to Vehicle (V2V) and Vehicle to Infrastructure (V2I) technology
- Contributing to Smart Cities that collect and process big data, often in real-time, to optimize transportation system performance (including more intensive use of shared infrastructure)
- Using connectivity to seamlessly guide data transfers between vehicles, infrastructure, and modes
- Assisting regional planning and the setting of transportation priorities through innovations that leverage limited dollars to create large positive impacts, for example by using Big Data to aid in multimodal planning, and the modeling of the movement of both people and goods
- Training the current and future transportation workforce to operate in an increasingly high-tech environment

To make all of this possible, C²M² must communicate its findings and tailor them for adoption in

the real world. This plan outlines our protocol for the planning, conduct, and dissemination of our Center's research efforts to further our ultimate goal: becoming a globally recognized innovation center that helps to transform multimodal mobility through data analytics, connectivity, and automation in order to have positive impacts on people's lives, society, and the economy.

2. IDENTIFYING STAKEHOLDERS AND THEIR INVOLVEMENT

2.1 Stakeholder Categories

The first and most crucial step in this Technology Transfer (T2) plan is to identify our main stakeholders. Stakeholders are vital to our efforts, from guiding the identification of problems to be solved, to financial support, to the adoption of innovations that result from our findings. Our stakeholders can be broken into three broad categories: government agencies, industry, and academia. Each of these groups has different needs, and thus our work is tailored to serve these various constituencies.

2.1.1 Government Agencies

Government agencies make up our biggest group of stakeholders and drive the majority of our research. Important agencies include:

- The U.S. Department of Transportation (USDOT)
- State departments of transportation like the Georgia Department of Transportation (GDOT) and the South Carolina Department of Transportation (SCDOT)
- Local and regional governments, such as Greenville, Richland and Charleston, Dorchester, Darlington and Lexington counties in SC, and the cities of Clemson, Orangeburg and Columbia in South Carolina;
- Port authorities such as the South Carolina State Ports Authority
- Councils of governments and metropolitan planning organizations (MPOs)
- Legislative bodies such as the U.S. Congress and the South Carolina State Legislature
- The Federal Railroad Administration (FRA)
- The U.S. Department of Homeland Security (DHS)
- The U.S. Department of Energy (DOE)

We look to the government bodies to help define the problems that our researchers seek to solve. To give some examples, our work on V2I infrastructure will aid government agencies at all levels in ultimately establishing connectivity between vehicles and roadside infrastructures (e.g., traffic signals) to ensure maximum throughput and safety at intersections. Our work on collecting, storing, and processing Big Data generated by various components of the transportation system will aid MPOs in travel demand forecasting.

We utilize our relationships with these various agencies to set up meetings where we can discuss precisely what needs they have and begin the planning process to cater to these needs. We seek to tailor our activities to workers at all levels of government, from elected officials and upper management (who help set our research priorities) to workers in the field (for whom we create training products). Once we have successfully completed a project for these agencies, we utilize a multi-pronged approach to disseminate our findings, as is outlined in this T2 plan. While our special focus is our region, the findings we disseminate are available to governments nationwide and even worldwide. Often time and money are

a factor in the feasibility of adoption for this category of stakeholder, so our projects are crafted with this in mind.

2.1.2 Industry

Our industry partners are another category of our integral stakeholders; partnering with this group allows our researchers access to technology, funds, and expertise beyond our Center. Due to the nature of our region, which is a major auto manufacturing hub, we are uniquely positioned to work with industry stakeholders, as we discuss further below. Since much of our research focuses on the next generation of in-vehicle communication and data-processing technology, our work is of great interest to private sector firms. Our relationship with industry helps us to identify other research needs, and often helps facilitate contact between our researchers and entities from government and academia as well. Our current industry partners include:

- Private sectors automotive firms like BMW and Volvo
- Software developers and vendors such as Trafficware, Cisco, Applied Information, and Traffic Technology Services, Inc.

Our industry partners bring unique resources to the table and often create an opportunity for our researchers to expand the scope of their research. Further, industry partners can reap great benefits from the technology we are developing. Finally, our industry partners have a broad reach and can facilitate the dissemination of our research results far beyond the immediate reach of our Center. Therefore, it is important that we cultivate these relationships; hence we engage industry partners at every step in the research and technology transfer process.

2.1.3 Academia

Our academic stakeholders are the cornerstone of our Center. The five schools in our consortium provide myriad resources to the Center, from the researchers who generate the projects we fund, to financial and in-kind support to the Center, to testing facilities, to aid in the identification of early potential adopters of our findings, to the resources and administrative support needed to spread our results. This group is made up of:

- The consortium of five schools making up our Center
- Local educational institutions outside our consortium, such as Tri-County Technical College and Greenville Technical College in South Carolina
- Universities across the nation with whom we collaborate in various fashions
- K-12 STEM teachers, SC Governor's School for Science & Mathematics, Bridge Creek Elementary School and Midland Middle School

Our academic partners are typically among our earliest adopters and offer a unique resource to help our researchers to refine our dissemination and technology transfer efforts. As with the groups above, we involve them at every step of the research process.

2.2 Stakeholder Involvement

Each of these stakeholder categories comes with its own specific needs, and thus we depend on these stakeholders to help guide what research we will undertake (for example by sitting on our Advisory Board and serving as reviewers for funding proposals), to help fund our research, to aid in the collection of data by our researchers, to furnish testbeds for our research, to deploy our innovations, and to assist in the

dissemination of the results of our research. We organize our approach to our relationships with these stakeholders based on the classifications laid out by the USDOT. Table 1 shows how these stakeholders fall into the categories identified by the USDOT. Our primary early potential adopters (EPAs) are our partners in the state and regional governments in South Carolina and our consortium of five schools. These are the stakeholders that C²M² has the closest relationships with, and from whom we have seen the biggest buy-in. These EPAs provide problems to be solved, an arena to conduct research and deploy innovations, and immediate feedback, making them invaluable to our Center.

Table 1 Stakeholder Categories and Potential Organizations

Stakeholder Categories	Potential Organizations
Sponsors of research and technology transfers	C ² M ² , State DOTs, MPOs, Councils of government, Industry partners
Researchers and developers	Five consortium members of C ² M ²
Deployment team	C ² M ² , State DOTs, Councils of government, Cities, Counties
Early potential adopters and problem owners	Five consortium members of C ² M ² , SCDOT, Regional governments (e.g., the cities of Clemson and Greenville), Industry partners, Nonprofits, Community colleges
Late potential adopters	State and federal DOTs, Industry (not partners), Nonprofit organizations (not partners)
Others	Transportation workforce in Upstate South Carolina and beyond, Professional bodies such as AASHTO, TRB, APTA and ITE

From the outset, we plan our work to meet stakeholder needs. For example, as noted above, we engage with stakeholders in the process of selecting projects for support by ensuring that representatives of government, industry, and academia review research proposals. We specifically request that they review proposals with issues of technology transfer in mind. Further, we require that these proposals explicitly address technology transfer, for example by considering technologies that will be developed, the potential benefits of technology transfer (such as improvements in traffic flow, multimodal coordination, monetary savings, and/or improved safety), the stakeholders who could adopt the technology, the pathways through which the results may be disseminated (such as conference presentations, publication in peer-reviewed journals, direct contact with stakeholders, research reports and the creation of prototypes), and the potential obstacles that might hinder rapid adoption and how these may be overcome. Further, a more detailed and specific technology transfer plan must be created by the research team after proposals are selected for funding. We provide researchers with appropriate guidance for how to create these plans to be sure that all relevant issues are addressed.

3. ASSISTING STAKEHOLDERS IN IMPLEMENTING AND DEPLOYING RESEARCH OUTPUTS

Our strategies for enlisting and working with stakeholders depends on their relationship to the technology being studied. We first approach partners for whom the technology is directly applicable, who have shown interest in the technology, and who may have close relationships with C²M² for reasons such as geographic proximity or past relationships with the research team. We put special emphasis on reaching out to stakeholders who could quickly implement the technology. Such potential partners are engaged intensively from the outset of the research planning process, particularly when they are prospective

sponsors of the research. For example, given that South Carolina is a hub for automotive manufacturing, we can leverage existing relationships we have built with local manufacturers, such as BMW, and Clemson's International Center for Automotive Research. We also can build on longstanding relationships with our state DOT. Due to the close proximity of many of these EPAs, we are fortunate to be able to meet in person with many of them. For those that we are unable to meet with regularly, we engage via email, phone, and/or web conferencing software, which allows our researchers to stay in constant contact with our stakeholder partners.

Stakeholders for whom the technology is less applicable or who have weaker ties to the Center may be approached later in the research process when results are more developed. Late potential adopters (LPAs) include other state DOTs and private firms with whom we are not directly collaborating. These LPAs are often willing to meet with our researchers and discuss the implementation of our research, but may be unwilling to deploy without further testing or data. It is important that C²M² and our affiliated researchers maintain a working relationship with these LPAs to build trust, which will lead to the adoption of our research and perhaps convert them to EPAs in the future. For potential stakeholders with weaker ties to our technology and Center, we have extensive public outreach efforts to generate potential initial interest that will lead to direct engagement. For example, our Center Director, Dr. Mashrur "Ronnie" Chowdhury and our post-doctoral fellow in technology transfer program lead efforts to generate initial contacts with agencies and firms with whom we are in the early stages of building relationships.

Our strategy for engaging stakeholders consists of:

- Identifying and making contact with appropriate persons within the stakeholder organization. This is where we communicate with the "problem owners," forming relationships that serve as a basis for many of our research projects. We engage them in the following manner:
 - In-person meetings
 - Via our email listserve (MailChimp)
 - Via social media (Twitter, LinkedIn, our C²M² website)
 - At industry conferences (CUTC, TRB, our annual Fall Conference)
 - Via our Transportation Technology Transfer Service (SC's Local Technical Assistance Program (LTAP) Center)
 - Through C²M² events and K-12 activities
- After initial contact, we establish a customized strategy for communicating with the particular stakeholder. Depending upon the organization and individual with which we are interfacing, we may set up recurring meetings, and communicate via phone, email or various video conferencing tools like Webex. C²M² also has a dedicated conference line that is utilized to facilitate meetings
- Upon learning of the stakeholder's needs, we analyze how the technologies we develop may meet these needs
- We identify potential barriers to adoption, such as regulation and market demand, and develop a strategy for how these obstacles may be overcome
- We determine potential pathways to adoption

4. DISSEMINATION OF RESEARCH OUTPUTS

C²M² principal investigators are responsible for disseminating the results of their project, but they are assisted by the Center and our established dissemination methods. To assist our researchers in this endeavor, C²M² has created the position of a Postdoctoral Fellow in Technology Transfer, who oversees all ongoing research projects, monitors progress, and aids in the dissemination of research outputs. Throughout the research process, the Fellow who holds this position guides and supervises researchers as they:

- Develop goals for the research that include technology transfer, and metrics by which the research and its technology transfer component will be measured
- Plan for the research results' adoption, including strategies to surmount any potential obstacles, such as regulatory, technological, legal and economic barriers
- Identify and make use of available resources for technology transfer, particularly those that can be furnished by C²M²
- Develop strategies to communicate results
- Monitor the adoption and performance of the technology

As we have noted, all proposals must specifically address the potential for technology transfer, including to academia, industry and government. Research proposals are reviewed by expert reviewers who select projects based in part on their potential for fruitful technology transfer. These reviewers may themselves become agents for the dissemination of the technology.

Our researchers are then tasked with reaching out to potential adopters and sponsors to determine what their needs are (both "functional needs" in terms of what the technology will accomplish, and "process needs" in terms of what steps are needed to secure adoption). Having identified and categorized potential stakeholders, C²M² helps researchers build relationships in order to drive our research, and develop and deploy results.

Researchers receiving funding from C²M² are tasked with providing quarterly updates about ongoing research, a report at the six-month mark, and a full report upon completion of the funded project. All ongoing research is outlined on the C²M² website, included in our quarterly performance reports, and submitted to the Transportation Research Board's Research in Progress website. This helps to promote collaboration and deployment and to avoid redundant research. The results of C²M² funded research are disseminated in myriad ways to encourage broad adoption of our research and development. Researchers affiliated with C²M² are expected to work with their partnering stakeholders in the dissemination of the results. A final report with the results is created for every funded project, as outlined by the USDOT in the UTC grant agreement. This report is:

- Submitted to our Center's directors
- Posted on our website
- Featured in our quarterly newsletter and listserv
- Submitted to the following organizations as decreed by our grant agreement:
 - Transportation Library
 - Volpe National Transportation Systems Center
 - Federal Highway Administration Research Library
 - National Technical Information Service

In addition, aided by C²M²'s guidance, resources, and network, researchers are encouraged to:

- Publish their findings in peer-reviewed publications
- Present findings at industry conferences such as the TRB conference, for which attendance may be funded by C²M²
- Present research at C²M²'s yearly conference
- Arrange pilot demonstrations of technologies where appropriate
- Develop workshops or webinars to disseminate results
- Seek out champions to adopt technologies and demonstrate their feasibility
- Utilize all other possible channels to communicate findings with all relevant stakeholders

Moreover, the Transportation Technology Transfer Service (T³S) at Clemson University is the technical assistance center for technology transfer activities in South Carolina. C²M² draws on the experience of T³S in its technology transfer activities. T³S promotes technology transfer by:

- Publishing a quarterly newsletter
- Offering training through topic-specific workshops and webinars
- Facilitating larger statewide conferences for multiple partners
- Managing training and certification programs

Part of the overarching goal of these dissemination efforts is to build the reputation of C²M² with the intention of enhancing our brand recognition and increasing the level of corporate support and partnership. As our researchers succeed and promote their research efforts, they are building a framework for future researchers funded by our Center to connect with new corporate partners, bring in additional stakeholders, recognize new problems to solve, and secure increased funding.

The communication plan runs throughout the research process, from discussing proposals for research all the way through getting feedback about lessons learned from the adoption of C²M² innovations in the field. We have found that our most successful dissemination engagement techniques have been via workshops and conferences, which provide an opportunity for our researchers to present their research via presentations/demonstrations and posters.

5. COMMERCIALIZATION PROCESS OF RESEARCH OUTPUTS

For the most part, the Center is focusing on developing research that is freely available to stakeholders to maximize C²M²'s societal impact. However, in some cases, it is appropriate to commercialize and license the technology. When this is the case, we follow the following steps:

- Research and development projects that create an invention or other entity requiring a patent are reported to C²M²'s lead institution, Clemson University, which aids the researchers in judging:
 - Whether the innovation is patentable
 - What the market demand for the innovation will be
 - How the innovation may be developed or improved for commercial adoption
 - What the pathway for securing adoption is
- If the research is promising for commercial exploitation:
 - Researchers from our partner schools first consult their institution regarding any

- potential patent and/or licensing procedures
- C²M² oversees the process of obtaining said patents or developing licensing arrangements while observing the guidelines established by the USDOT
- For projects at Clemson, C²M² works with the Clemson University Research Foundation (CURF) to research and obtain patenting, and for the disclosure and collection of royalties or associated funds

Commercialization of our technology is achieved via licensing intellectual property (IP) by leveraging the technology transfer expertise of CURF. The commercialization process of our research outputs entails the following steps:

- Invention Discovery
 - C²M² works with faculty to identify potential inventions
 - C²M² provides assistance in identifying potential markets as a part of identifying commercialization pathways for research results of the faculty
- Invention Disclosure
 - C²M² works with Center researchers to disclose research outputs to CURF
 - CURF and C²M² notify Center members of the invention disclosure
- Invention Evaluation
 - CURF and C²M² review invention conduct, such as a patentability search, market review, and commercialization analysis
 - CURF and C²M² provide information to inventors and collaborating institutions
- Intellectual Property (IP) Protection
 - CURF and C²M² work on an agreement between researchers of partner institutions (Benedict College, The Citadel, Clemson University, South Carolina State University and University of South Carolina) on an IP protection strategy based on their evaluation and input
 - CURF and C²M² lead the management of any IP in conjunction with an inter-institutional agreement (IIA) executed between the inventor institutions and partner institutions
- Marketing
 - CURF and C²M² develop and implement a marketing strategy in conjunction with the Center members
 - CURF and C²M² utilize online and direct marketing techniques to engage potential licensees
- Licensing
 - CURF and C²M² utilize a combination of exclusive and or non-exclusive licensing strategies to engage licensees
 - CURF and C²M² target multiple industry segments for commercialization by utilizing multiple fields of use based on technology application

6. COLLECTION AND USE OF LICENSING REVENUES

When applicable, funds from the commercialization of our technology are used to support additional research endeavors. Licensing revenue is apportioned between the Center members based on inventive contribution after an inventor receives his/her portion. The lead institution, Clemson University, takes the commercialization lead in partnership with its designated technology transfer entity, CURF. The IIAs govern the share of any licensing revenue and patent expenses between the parties. Each member institution distributes any licensing revenue in accordance with their respective technology transfer and intellectual property policies. All revenues originating from research discoveries returned to C²M² by Clemson University are used to fund transportation research by faculty and graduate students. CURF uses any reimbursement for patent costs to help sustain its ability to protect discoveries. Similar policies and revenue-sharing agreements are in place at all C²M² institutions.

7. TECHNOLOGY TRANSFER GOALS AND PERFORMANCE MEASURES

In this section, C²M²'s goals and performance measures related to technology transfer are presented.

7.1 Goals

Our Center has the following goals for our technology transfer effort:

- Disseminate C²M²'s research results to a large audience utilizing different research distribution media
- Develop new methods or products based on C²M²'s research
- Demonstrate developed technologies
- Train the current and future transportation workforce to operate in an increasingly high-tech environment
- Incorporate new technologies (software and/or hardware) and/or techniques and/or practices that are deployment ready
- Improve technologies and/or processes in addressing transportation issues
- Increase adoption of new technologies, methods or practices based on C²M²'s research
- Improve transportation system operations and/or transportation safety and/or quality of life

7.2 Performance Measures

We have used these goals to create our performance measures. Our technology transfer goals are connected to the performance measures to evaluate the success of our T2 efforts. Table 2 shows the research performance measures that C²M² will use to gauge our progress. The research performance measures (3rd column of Table 2) provide the information related to how we will judge success in measuring the outputs, outcomes and impacts of our research. Our methods for tracking these outputs, outcomes and impacts appear in Section 8.

Table 2 Goals, Research Performance Measures and Annual Targets for T2

No.	Goals	Research Performance Measures	Target per year
Outputs			
Output #1	Disseminate C ² M ² 's research results to a large audience utilizing different research distribution media	Number of technical reports published	5
		Number of conference presentations	20
		Number of peer-reviewed papers published	10
		Number of conferences solely based on C ² M ² 's research	1
Output #2	Develop new methods or products based on C ² M ² 's research	Number of new and/or improved research methods or products	10
Output #3	Demonstrate developed technologies	Number of pilot demonstrations of technology	3
Outcomes			
Outcome #1	Train the current and future transportation workforce to operate in an increasingly high-tech environment	Number of training events and workshops	2
Outcome #2	Incorporate new technologies (software and/or hardware) and/or techniques and/or practices that are deployment ready	Number of new technologies, and/or techniques and/or practices that offer implementation or deployment guidance	4
Outcome #3	Improve technologies and/or processes in addressing transportation issues	Number of improved technologies and/or processes disseminated from C ² M ² funded research projects	4
Impacts			
Impact #1	Increase adoption of new technologies, methods or practices based on C ² M ² 's research	Number of cases of adoption by transportation agencies and/or commercialization of C ² M ² 's technologies, methods or practices	2
Impact #2	Improve transportation system operations and/or transportation safety and/or quality of life	Number of cases of C ² M ² 's research that resulted in societal benefits, such as lives saved, congestion reduced, and fuel conserved through changing behavior, practices, decision making, policies (including regulatory policies), and/or social actions	2

8. TRACKING AND REPORTING RESEARCH OUTPUTS, OUTCOMES, AND IMPACTS

Research outcomes, outputs, and impacts are tracked by the Center in several ways. Principal investigators are responsible for providing initial results to their specific institution's Associate Director and our Technology Transfer Specialist, who then pass those results on to our Program Coordinator and the Center Director. In turn, these results are reported to the USDOT and public through the release of our semi-annual Program Progress Performance reports, our yearly Performance Indicator report, and our yearly Technology Transfer report. These reports outline the tangible results of all sponsored projects, and in addition to being submitted to the USDOT they are made available to the public via our Center website, newsletter, and email listserv. We use our website and listserv service to then track engagement, such as determining the number of clicks and downloads.

9. STRATEGY FOR INCREASING CORPORATE RESEARCH SUPPORT

We expect to see an annual increase in the number of proposed projects supported by corporate partners. To accomplish this, our Director and our Associate Directors aggressively solicit proposals from colleagues at their respective schools and pursue outside funding from government (e.g., SCODT), and industry partners and universities. We use a range of strategies to increase corporate research support through expanding upon industry-sponsored research and increasing private industry's access to C²M² faculty and students.

Technology Marketing Strategy: The developed technologies are marketed through a campaign of direct solicitation, presentation at various innovation forums, and directly through our website. A broad dissemination of project data and results are fostered through publication in high-impact journals and a dual-licensing strategy that allows for free use by non-commercial entities with the goal of demonstrating the value of, and creating market interest in, our developed products. Our researchers also promote their technologies through live demonstrations at different workshops and conferences. These build a framework for future researchers funded by our Center to connect with new corporate partners.

Research Funding Strategy: Our Center prioritizes funding of those research proposals which have at least one actively involved industry partner. This contributes to the real-world applicability of research and outcomes. We also motivate our industry partners to host students for summer internships beyond their regular participation in Center activities.

Transportation Industry Support: As has been noted, a number of the world's leading transportation firms have major facilities in South Carolina, including Michelin, Boeing, BMW, and Volvo. Our Center has the greatest potential for transportation-related corporate research support from these companies. For example, BMW had a successful collaboration with Clemson University related to artificial Intelligence-based data and transportation infrastructure to support connected autonomous vehicle operations, as well as data analytics to support automotive and transportation systems.

Research Support from C²M²'s Partner Institutions: Our partner institutions provide support for our research projects. For example, Clemson University provides access to the traffic signals and roadway corridors in conjunction with the city of Clemson in South Carolina for our connected autonomous vehicle testbed, which is the key element for the Center's foundational research project (i.e., Development of Cyber-Physical Systems for Connected and Autonomous Vehicle Research). Access to this testbed is made available to all C²M² researchers to facilitate their research projects. We see strong potential for the commercial and public sector adoption of technologies developed with this testbed, such as the connected vehicle application development platform (CVDeP) and software-based V2I/I2V interfaces cybersecurity platform, CVGuard. Clemson also supports our research by fostering collaboration between

the Clemson University – International Center for Automotive Research (CU-ICAR) and our Center. Further, Clemson’s Division of Research partners with our Center to sponsor bringing leading researchers from both industry and academia to Clemson to discuss potential research collaborations. Our other four partner institutions are providing similar support to researchers at their institutions.