Navigating Trade-Offs in Complex Systems: Deliberative Multi Criteria Decision Analysis of CCMPO Metropolitan Transportation Plan, 2010-2035

Navigating Trade-Offs in Complex Systems: Deliberative Multi Criteria Decision Analysis of CCMPO Metropolitan Transportation Plan, 2010-2035
Sponsoring Agency: UVM Transportation Research Center

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Executive Summary

Metropolitan Planning Organizations (MPOs) are required by Federal law to develop a long-range Metropolitan Transportation Plan (MTP) at least every five years. This research focuses on assessing the trade-offs between business-as-usual MTP scenario of gasoline driven transportation infrastructure and suburban growth with two alternate sustainable community design scenarios in Chittenden County Metropolitan Planning Area (CCMPO). The CCMPO adopted its last long-range transportation plan in 2005 for a temporal horizon of 2005 to 2025 and is currently updating 2025 MTP to 2035 MTP. We implemented two focus groups with multiple stakeholder representatives of the regional transportation planning network and conducted numerous interviews to implement a participatory multi-criteria evaluation of 2035 MTP scenarios. Three MTP scenarios are evaluated on twelve decision criteria: operational performance, sustainable land-use, safety and accessibility, minimize time and total costs, protect built and natural environs, community development, access and mobility, transportation system efficiency, energy efficiency and conservation, improve alternate travel modes, public education and cost effective and inclusiveness. Our analysis reveals that the underlying expected value functions of all stakeholder representatives in the regional transportation planning network overwhelmingly reject business-as-usual MTP scenario. Instead, a more sustainable, growth contained community design scenario emerges with the highest expected value for all stakeholder groups. Formal implementation of sustainable community design scenario would, however, require CCMPO and regional transportation planning network actors to overcome a series of legal, political and economic challenges. We discuss the implications of these trade-offs, challenges and opportunities on the development and implementation of sustainable community designs.

1. Introduction
1.1. Research Background

Metropolitan Planning Organizations (MPOs) are required by Federal law to develop a long-range transportation plan (or MTP) at least every five years. This document must include the strategies, actions and projects that will lead to *"an integrated multimodal transportation system to facilitate the safe and efficient movement of people and goods..."* Federal funds cannot be used for projects and services unless they are consistent with an adopted long-range plan. The MTP must also be financially constrained by a reasonably expected level of transportation funding. The Chittenden County MPO (CCMPO)[1] adopted its last long-range transportation plan in 2005 for a temporal horizon of 2005 to 2025. This plan, referred to as the 2025 MTP, identifies the major transportation projects, programs and policies needed over the planning period, and establishes the vision and goals that will guide public decisions affecting transportation facilities and services in the County. The CCMPO is currently working on producing a 5-year update to 2025 MTP, which initially looked at an expanded horizon of 50 years covering the period 2010 to 2060 (2060 MTP); however, later on, rescaled back to 2010-2035 horizon. The 2035 MTP is expected to oversee about $30 million federally funded transportation investments per year in the Chittenden County area. Initial workshops were organized by CCMPO in 2009 and early 2010 to develop a short list of two to four scenarios, in addition to a baseline business-as-usual scenario, for the CCMPO transportation system boundaries.

A review of draft 2060/2035 MTP decision making documents and preliminary interviews with MPO staff pertaining to this decision making process identified an interesting and potentially very useful "participatory action research" opportunity in terms of explicating the inherent trade-offs confronted in finalizing an alternate scenario as a transportation plan that adequately meets the twelve decision criteria (shown in Table 1-1), which were extracted from the MTP steering committee goals laid out in 2025 MTP (pages 11-12) and expected to be retained in the planning for 2060/2035 MTP. The 2025 MTP was developed without explicitly assessing value trade-offs in prioritizing one plan over other potential combination of alternate plans. With the explicit treatment of trade-offs for 2060/2035 MTP, the decision makers (especially CCMPO board members) could potentially choose a plan that maximizes the potential attainment of mutually agreed upon twelve decision criteria. The proposed research plan aimed at implementing a deliberative Multi Criteria Decision Analysis (MCDA) to elicit value trade-offs and generate multi-criteria expected value functions for comparing the baseline with alternate 2035 MTP scenarios.

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[1] More information about CCMPO and their 2025 MTP and 2060 MTP planning processes is available at www.ccmpo.org

Table 1-1: Decision Criteria elicited from MTP Steering Committee Goals

Decision Criteria (C$_j$)	MTP Steering Committee Goal
1. Operational performance	Preserve and improve the physical condition and operational performance of the existing transportation system.
2. Sustainable land-Use	Reinforce sustainable land use patterns, such as growth centers, as set forth in local and regional plans.
3. Safety and accessibility	Create a transportation system that offers constantly improving safety, accessibility, flexibility, and comfort for everyone.
4. Minimize time and total costs	Establish a transportation system that minimizes the time and total cost of moving people and goods, allowing the region's economy to thrive.
5. Protect built and natural environs	Protect or enhance the region's built and natural environments
6. Community development	Create a transportation system that builds community, enhances neighborhood vitality, and minimizes noise, glare, and vibration.
7. Access and mobility	Provide levels of access and mobility that insure people and goods can travel when and where they need to go.
8. Transportation system efficiency	Consider ways to improve transportation system efficiency before increasing transportation capacity
9. Energy efficiency and conservation	Establish a transportation system that uses diverse sources of power and maximizes energy efficiency and conservation
10. Improve alternate travel modes	Develop a transportation system that features a variety of travel modes and encourages the reduction of single-occupant vehicle use
11. Public education	Educate the public—from children to seniors—about the implications of different development patterns and mode choice decisions
12. Cost effective and inclusive	Provide improvements to transportation facilities and services expeditiously through an inclusive and cost effective process

1.2. Theoretical Background

There are competing theories of policy and planning evaluation that have been proposed in different disciplines to account for environmental and socio-economic impacts of anthropogenic activities, including transportation activities, at multiple space-time scales. Neo-classical economists' theory of total economic valuation [1] monetizes anthropocentric values. Recent advancements in decision theory and behavioral economics theory have cast a long shadow over the "willingness to pay" (WTP) monetization estimates of anthropocentric values [2]. Norton and Noonan (2, p. 665), for example, state: "What worries us is that the current enthusiasm for ecosystem service methods (used in tandem with contingent valuation methods) has locked the rhetoric of environmental evaluation in a very monistic, utilitarian, and economic vernacular that leaves little or no room for other social scientific methods, or for appeal to philosophical reasons or theological ideals. It also discourages a

more profound reexamination of how one might create a rational process of policy evaluation that truly takes into account both economic and ecological impacts of our decisions." Norton and Noonan (*2*, p. 665) provide persuasive arguments to reject the "monistic, utilitarian" theory of valuation. Instead, they argue for the development of "a new, pluralistic, multi-scalar, and multi-criteria method of evaluating anthropogenic changes to natural and social systems."

Outlining the elements of a pluralistic, multi-scalar theory of valuation, Norton and Noonan (*2*, p.672) suggested a shift in the unit of analysis to development paths or scenarios. "Development paths are ways our community/place can develop over time and into the future. Development paths can be thought of, alternatively, as scenarios, but here scenarios are used creatively and reflectively, to explore and evaluate possible scenarios according to multiple criteria and not, as in economic models, as a methodological tool to measure welfare change. Proposed policies can be understood as interventions to modify or stabilize systemic effects on community or place, and simulations can be used to explore how policy options might lead to varied scenarios. Goals can be set, not as abstract principles that demand maximization of a single index value (e.g., economic welfare) but as descriptions of favored development paths. Proposed policies, and the development paths they are modeled to shape and encourage, can then be evaluated on multiple criteria, including economic criteria (such as job creation and comparative efficiency of different institutional means to achieve improvements on key criteria), but also including longer-term impacts on ecological systems. So, we are proposing an alternative approach to evaluation of environmental change, which shifts the unit of evaluative analysis from WTP for atomized, discrete commodities, or clearly describable changes in scenarios, to development paths that can be evaluated according to impacts on multiple scales of time and space. In this way we can choose development paths to protect a range of human values, recognizing the multiple ways humans value nature." (*3*, p. 672)

A number of studies have recently been published that demonstrate the applicability of a non-monistic, value pluralistic, multi-criteria theory of policy and planning evaluation with a Habermasian deliberative bent of communicative action [3], [4], [5], [6], [7], [8], [9], [10]. This body of literature has emerged in parallel to the deliberative value focused decision analytic models [11], [12], [13], [14], [15]. Kiker et al.[16] present a broad review of studies that involve the application of multiple criteria decision making models for environmental decision making. Major limitations of deliberative multi-criteria evaluation methods are discussed by Hisschenemoller and Hoppe[17]; Pellizzoni [18]; Shim et al.[19]; Stirling[20]; and Wittmer et al.[21].

This research project tested a deliberative MCDA methodology (discussed below) in the broader theoretical context of Norton and Noonan's [2] pluralistic, multi-scalar, and multi-criteria theory of policy and planning evaluation. The deliberative MCDA was applied as a "participatory action research" intervention in the current deliberations going on in CCMPO for designing 2060/2035 MTP. The application of this deliberative methodology was tested in the specific context of eliciting value trade-offs inherent to pursuing alternate transportation planning scenarios.

1.3. Outline of the Report

Section 2 describes research methods, especially deliberative MCDA methodology that was implemented with multiple stakeholder focus groups in the fall of 2010. Section 3 presents results. Section 4 discusses implications of these results. Conclusions are presented in Section 5.

2. Research Methodology

2.1. Analytical Methodology

MCDA enables elicitation of value trade-offs as a structured participatory mechanism for groups of multiple stakeholders to iteratively discuss incommensurate values and evaluate the weights on those values for choosing valuable actions. Building upon Norton and Noonan's[2] idea of alternate development paths/scenarios, as implemented by Zia et al.[22] a multi-criteria expected value function V_i for ith scenario/development path in a set of m development paths is formally defined, as in

Equation 1:

$$V_{ik} = \sum_{i=1}^{n} w_{jk} x_{ijk}$$

$$s.t. \sum_{j=1}^{m} w_{jk} = 1$$

Where w_j is a constant-sum weighting or Trade-Off *function* for jth criterion in a set of m criteria (by a group of K stakeholders); and x_{ijk} is an "outcome" or "impact" function for ith scenario on jth criterion as perceived by a kth stakeholder in a group of K stakeholders and among N scenarios.

For an individual or an institutional decision maker, the most valued scenario is the one with the highest V_i. The real challenge is how to integrate/aggregate V_i across groups of multiple stakeholders for choosing a development path that reflects the pluralistic values of all affected stakeholders (More information on this can be found in Zia et al.[22]). For this very reason, as argued by Martinez-Alier and Munda[23], we propose the deployment of deliberative and softer version of MCDA applications. In particular, we propose a continuous and iterative application of an open ended 8-step deliberative procedure, as shown in Table 2-1.

Table 2-1: Procedural heuristic of deliberative MCDA

Steps	Procedures
1.	Develop a group consensus on alternative scenarios/development paths
2.	Develop a group consensus on criteria (mutually exclusive and typically incommensurate)
3.	Individuals assign weights on criteria
4.	Individuals assign their perceived outcome on a common scale for each alternative by each criterion
5.	Individuals participate in small group discussion to develop consensus on weights and perceived outcomes
6.	Workshop level weights and perceived outcomes are developed
7.	Workshop level weights and perceived outcomes are multiplied to evaluate design alternatives
8.	The evaluation process is repeated iteratively with different set of stakeholder representatives

The PI had designed and pilot tested these MCDA protocols to assess the valuation trade-offs among alternate management plans for complex conservation versus development planning problems in Tanzania, Peru and Vietnam as part of the MacArthur Foundation grant, two research articles [22], [24] have so far emerged out of this MacArthur foundation sponsored work that further elaborate the topics of navigating trade-offs in complex systems as well as deliberative multi-criteria decision analytical methodologies. These methodologies were adapted to evaluate the trade-offs among multiple criteria in processing CCMPO MTP planning process, in particular comparison of three alternate scenarios that were developed by CCMPO prior to this research intervention.

Prior to the implementation of this project, the CCMPO had organized public workshops to finalize 3 alternate scenarios, which means step 1 of the protocol laid out in Table 2-1 was already implemented. Further, the CCMPO 2060/2035 MTP committee had approved the continued usage of 12 valuation criteria, shown in table 1-1, which were earlier agreed upon for finalizing 2025 MTP, which meant step 2 in Table 2-1 protocol was also agreed upon. While steps 1 and 2 of Table 2-1 were already implemented in the current 2060/2035 MTP design process, we intervened in the process to revisit some nuanced details about the process of comparing among 3 alternate scenarios with respect to multiple stakeholder value-trade-offs.

2.2. Alternate MTP Scenarios

The CCMPO[25] developed three 2060/2035 MTP scenarios: loosely labeled as a trend scenario, a workshop scenario and a core scenario. As shown in Figure 2-1 below, the **Trend Scenario** depicts a development pattern and density likely to be seen on the Chittenden County landscape should the current trends of the past 30 years persist 50 years into the future. The pattern could be described as single family or low density housing/commercial uses on large lots. This trend consumes land at a high rate by spreading uses such as buildings, driveways and parking across large areas. The advantages of this type of development are solitude and elbow room for residents and workers in these areas. Disadvantages with this type of development pattern are that it often requires more spending on public services like roads, water, sewer, and emergency services which are more costly given the distances between houses/buildings as well as from town centers. Another disadvantage is the fragmentation of open land currently used for agriculture, forestry, and wildlife habitat [25].

In contrast, the **Workshop Scenario** is representative of the recommendations generated at the Fall 2008 CCMPO Scenario Planning workshops. The workshops were held around the county and resulted in 12 separate maps that, when closely examined, were variations on the same theme - a diffused centers pattern. Features include new clustered and higher density development assigned to areas adjacent to existing development; some additional build up of existing centers; and very limited development in rural areas. The differences between the 12 workshop maps varied only in where, and at what densities, the clusters were placed. The intensity and location of these centers impacts the provision of services to and within them. Advantages of this type of development include cost efficiencies on services like roads, water, sewer, and emergency services as well as the preservation of open space. This denser development and mixed use concentrated in smaller clusters may create a more urban atmosphere with less privacy and may be seen as a disadvantage by some. This type of development could require revisions to local zoning regulations in order to allow higher densities [25].

Finally, the **Core Scenario** takes a radical departure from recent trends and concentrates growth in fewer places. More specifically it would result in locating 45% of all new households over the next 50 years into Burlington and another 5% in Winooski. These cities have grown slowly over the last several decades making this scenario a dramatic reversal in historic trends. Such intensity of development in what have been slow growing places would require significant revisions of existing development regulations and public acceptance of high density zoning. This scenario will result in much denser neighborhoods in Burlington and Winooski which may change the character of those municipalities and give them a more urban feel. The benefit of this type of development pattern would be significant cost savings in the provision of municipal services and contribute to more opportunities for taking buses or other public transportation and walking and bicycling. Areas outside the urban core would receive less growth and much of the rural areas would remain relatively open.

Figure 2-1: Trend, Workshop and Core Scenarios
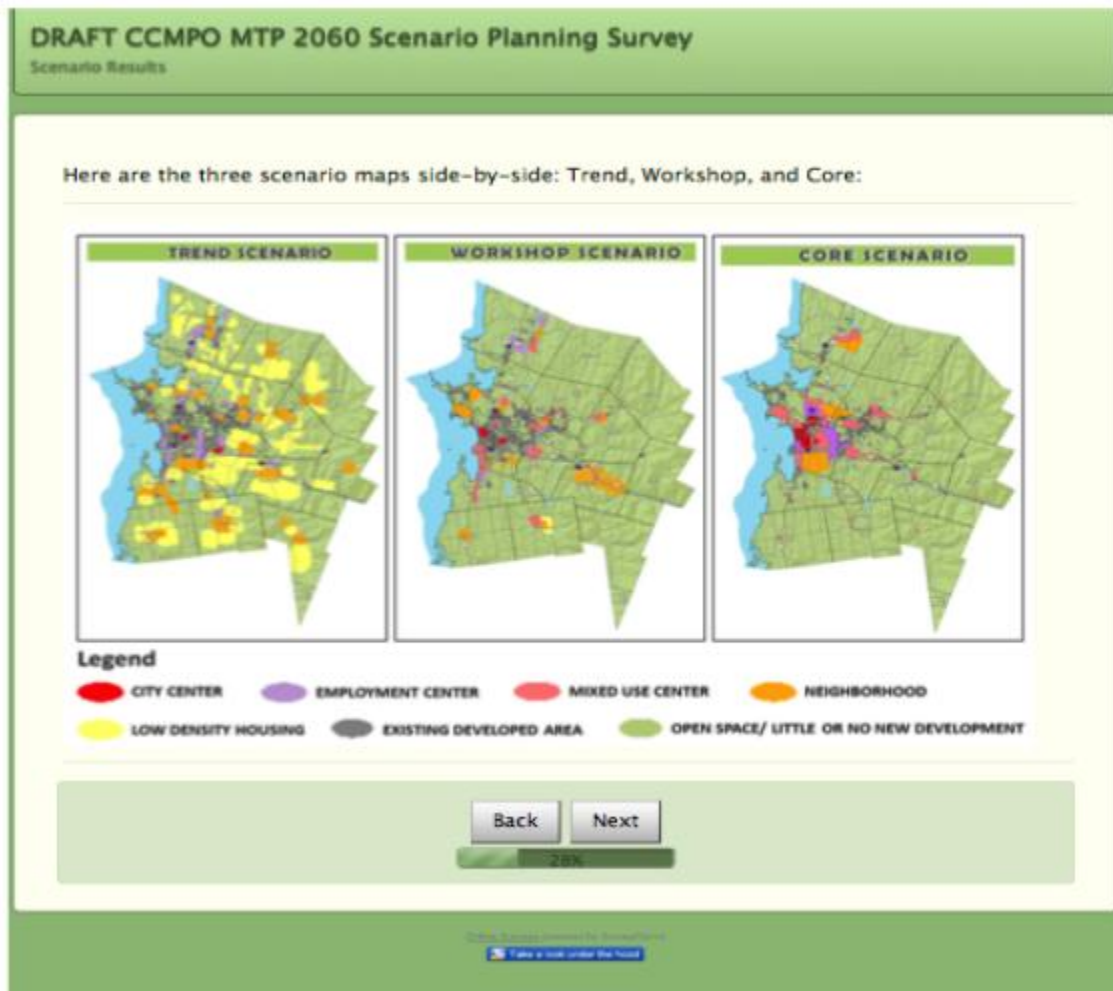
2.3. Data Collection Procedures

For this project, we implemented deliberative MCDA protocol shown in Table 2-1 by organizing two one-day focus groups on September 25 and 28, 2010 in Burlington. Agenda of the focus groups is attached at Appendix A. The focus group protocols were approved by UVM IRB. For each workshop, we brought together 8 to 10 participants representing different stakeholder groups who were engaged in short, medium and long range transportation planning processes. These stakeholders represented CCMPO board members and technical staff, RPC, VTRANS, US DOT/FHWA, and CSOs. Each workshop was run from 8:30 am to 4 pm at the CCMPO's conference room and the participants were paid a modest amount of compensation for devoting their time. Both the workshops had different set of participants, facilitated by PI and co-facilitated by Professor Chris Koliba. The proceedings of both the focus groups were audiotaped for post-workshop qualitative and quantitative data analysis. Most importantly, focus group participants were asked to provide their constant-sum weights for the 12 criteria (Table 1-1). The impact functions (Xij) for three MTP scenarios vis-à-vis these 12 criteria were separately calculated either from CCMPO[25] or through expert interviews. Appendix B shows the proxy variables and their assumed values for all Xij. These impact functions were normalized using a linear normalization procedure[26]. Normalized values are also shown in Appendix B. In future research, a sensitivity and/or Monte Carlo analysis of the assumptions about these impact functions is recommended.

Focus group data that pertains to short and medium transportation planning processes is being separately analyzed for a project prioritization pattern study. Findings from this aspect of the analysis are presented in Koliba et al.[27] and Zia et al. [28]. In this report, the analysis of focus group data with respect to long range MTP process is presented. Further, in the discussions section, implications of our research findings with respect to the relationship between long, medium and short term planning processes are briefly discussed in the light of focus group data.

3. Results

Table 3-1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
1. Operational performance	14	10.45214	7.092395	0	30
2. Sustainable land-Use	14	13.30929	10.75414	0	40
3. Safety and accessibility	14	10.30929	8.187466	1	30
4. Minimize time and total costs	14	5.880714	3.835359	0	10
5. Protect built and natural environs	14	10.52357	8.384744	3	30
6. Community development	14	7.095	2.877533	3	10
7. Access and mobility	14	7.380714	4.785713	1	20
8. Transportation system efficiency	14	6.452143	3.685385	1	10
9. Energy efficiency and conservation	14	12.73786	9.694752	1	40
10. Improve alternate travel modes	14	7.737857	4.533184	1	15
11. Public education	14	4.880714	5.683239	0	20
12. Cost effective and inclusive	14	4.737857	3.649308	0	10
13. Trend_ev	14	58.14803	5.564844	46.28577	66.83409
14. Workshop_ev	14	74.16861	6.427547	67.12908	91.64055
15. Core_ev	14	94.87912	3.547966	90.03831	100

Table 3-1 shows descriptive statistics from the constant-sum weight data as well as expected value functions estimated for 14 workshop participants. If we assume equal weight for each of the 14 focus group participants, Table 3-1 shows that participants assigned highest weight of 13.30% points for sustainable land-use while lowest weight was assigned to cost-effective criterion. Among the three scenarios, core scenario has the highest expected value of 94.87% points, followed by workshop scenario at 74.16% points. Least preferred scenario is the trend scenario at 58.14% points.
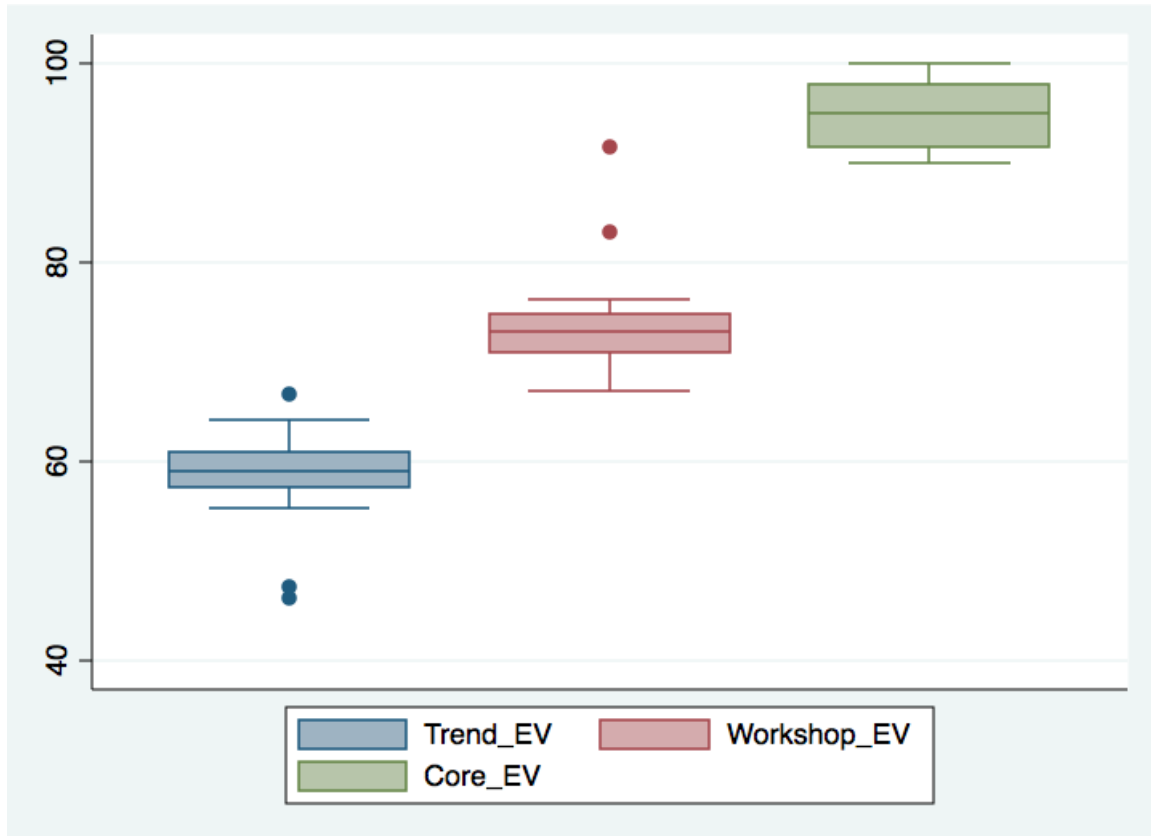
Figure 3-1: Boxplots of expected values from three scenarios

Figure 3-1 shows that the expected value for core scenario is significantly higher than the other two scenarios. Despite small sample size (N=14), this significant result shows the broader underlying consensus of the workshop participants for the core scenario. There are two significant trade-offs that appear to be made by the participants: First, core scenario entails higher upfront costs (as shown in the cost-effective impact factor in appendix B), which are traded-off by assigning higher weights for sustainable land-use criterion. Second, core scenario implementation through the planning process will require significant modifications in the current land-use and zoning practices in Chittenden County (especially the famous Act 250). This second issue was explicitly raised by many participants during the focus group discussion and is further addressed in the discussion section.

Despite the clear preferences derived in the above analysis, there are many complex factors that appear to reflect the variability in the assignment of weights on 12 decision criteria. Figure 3-2 below shows box plots of assigned weights for these 12 decision criteria. Many criteria display large variability, which means that aggregate results will need to be further dissected by each stakeholder group for a deeper analysis of stakeholder preferences and weights.

Figure 3-2: Boxplots of weights for decision criteria
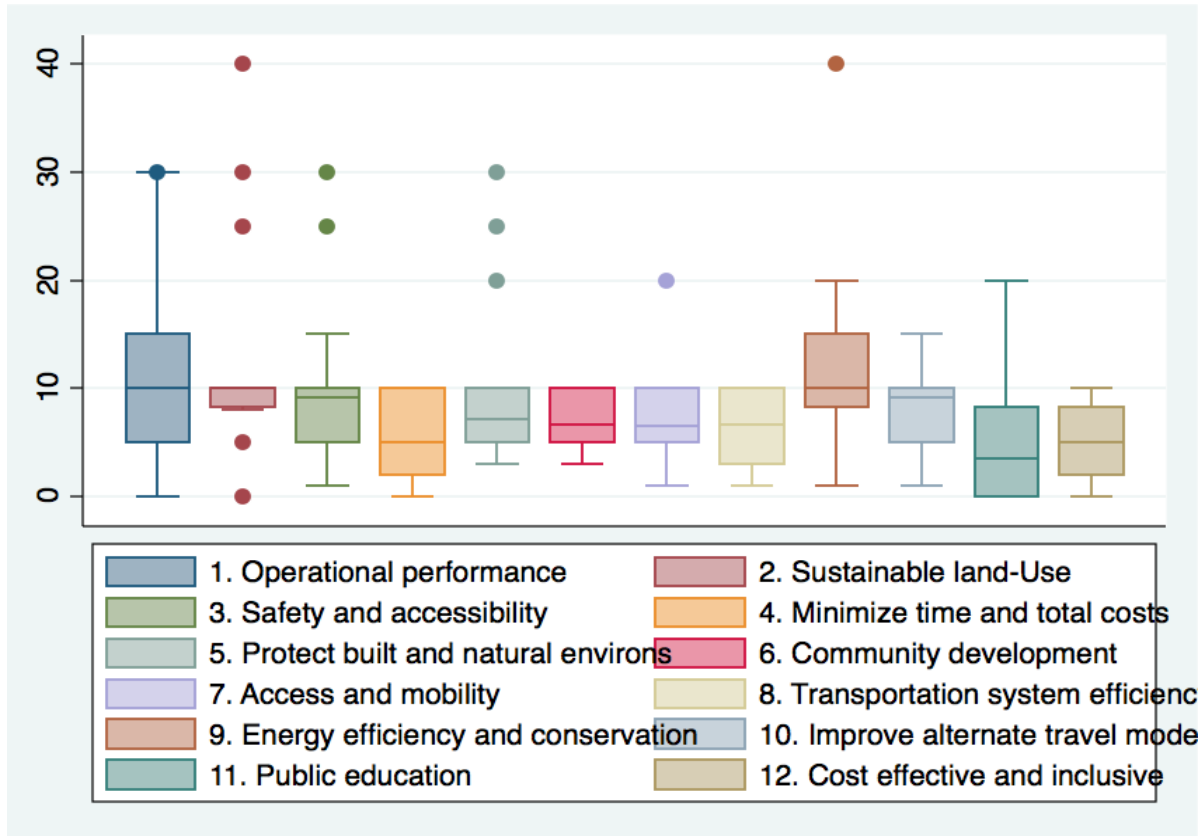
To further assess this variability in the assignment of weights, analysis of various between stakeholder groups was implemented, as shown in Table 3-2. The null hypothesis of constant variance across the following decision criteria is rejected: Sustainable land-use; safety and accessibility; community development; access and mobility and transportation system efficiency.

Table 3-2: Analysis of Variance Between Stakeholder Groups for Constant-Sum Weights Assigned on Decision Criteria

Decision Criteria	Weights	
	SS (MS)	F (Prob>F)
1. Operational performance	373.82 (41.53)	2.42 (0.2043)
2. Sustainable land-Use	1501.61 (166.84)	358.95*** (0.0000)
3. Safety and accessibility	851.52 (94.61)	12.77** (0.0129)
4. Minimize time and total costs	161.60 (29.62)	2.42 (0.2043)
5. Protect built and natural environs	827.59 (91.95)	3.82 (0.1049)
6. Community development	105.85 (7.39)	6.36** (0.0452)
7. Access and mobility	199.82 (22.20)	12.01** (0.0145)
8. Transportation system efficiency	168.38 (18.70)	5.77* (0.0533)
9. Energy efficiency and conservation	740.10 (82.23)	3.86 (0.10)
10. Improve alternate travel modes	243.94 (27.10)	3.66 (0.1120)
11. Public education	271.38 (36.71)	3.28 (0.13)
12. Cost effective and inclusive	144.45 (16.05)	2.06 (0.2533)

* Significant at 90%
** Significant at 95%
*** Significant at 99%

Figure 3-3 shows variability in the probability density functions of adjusted weights for each of the 12 decision criteria. Each of the 12 decision criteria has a unique distribution function, which implies that there is large variability in the stakeholder preferences for these decision criteria. Further, Figure 3-4 shows variability of these weights by different stakeholder groups represented in the focus groups. While these are not statistically representative samples of each of the represented stakeholder groups, each of these stakeholder groups appears to have different distributional function for the 12 distribution criteria (represented on the x-axis in Figure 3-4).

Figure 3-3: Probability density functions of weights for decision criteria
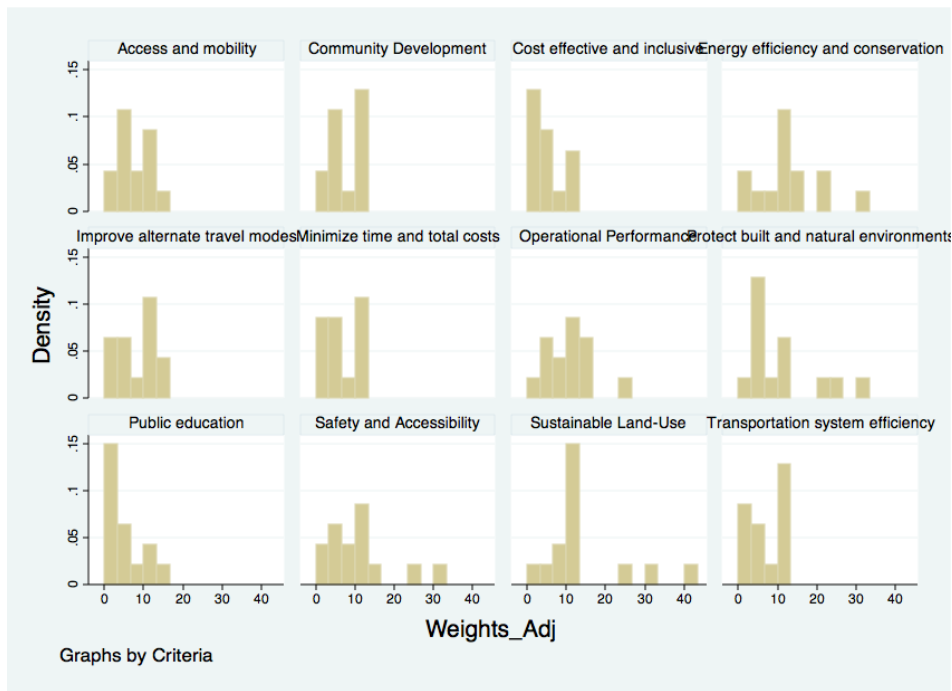
Figure 3-4: Distributional functions of average weights by stakeholder groups

Graphs by Group
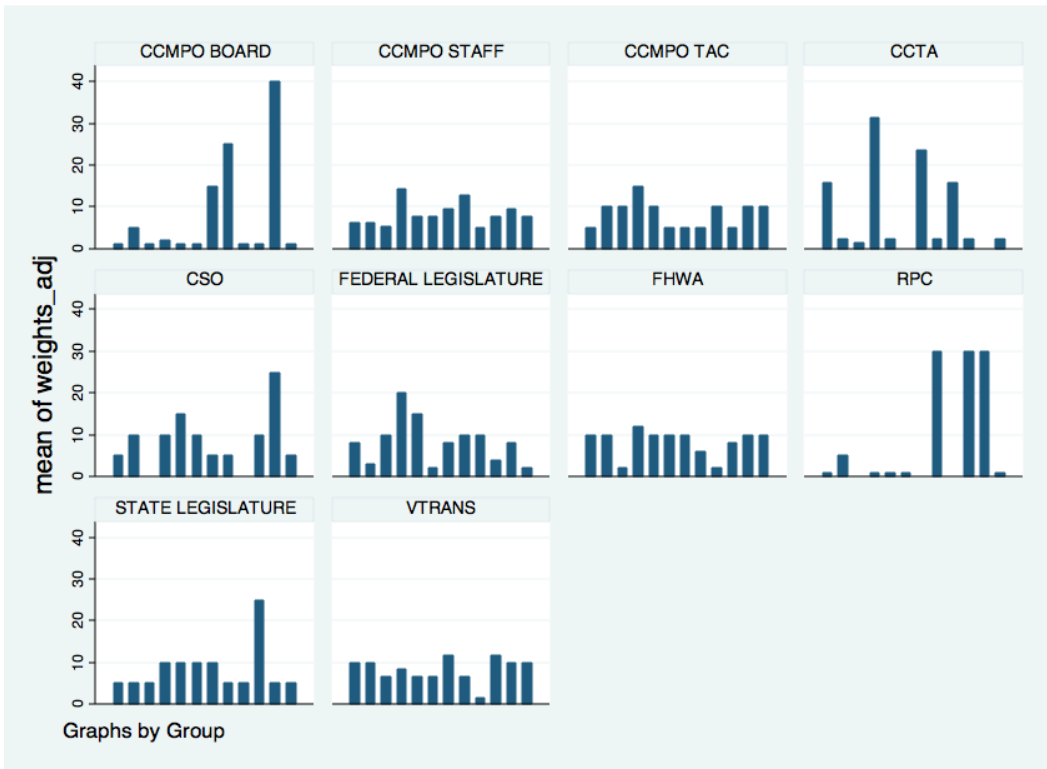
In terms of expected values for each of the three scenarios, we find that almost all stakeholder groups represented in the focus groups consistently display higher expected value for the core scenario, followed by workshop and trend scenarios respectively, as shown in Figure 3-5.

Figure 3-5: Expected values for each of the three scenarios by stakeholder groups

Graphs by Stakeholder
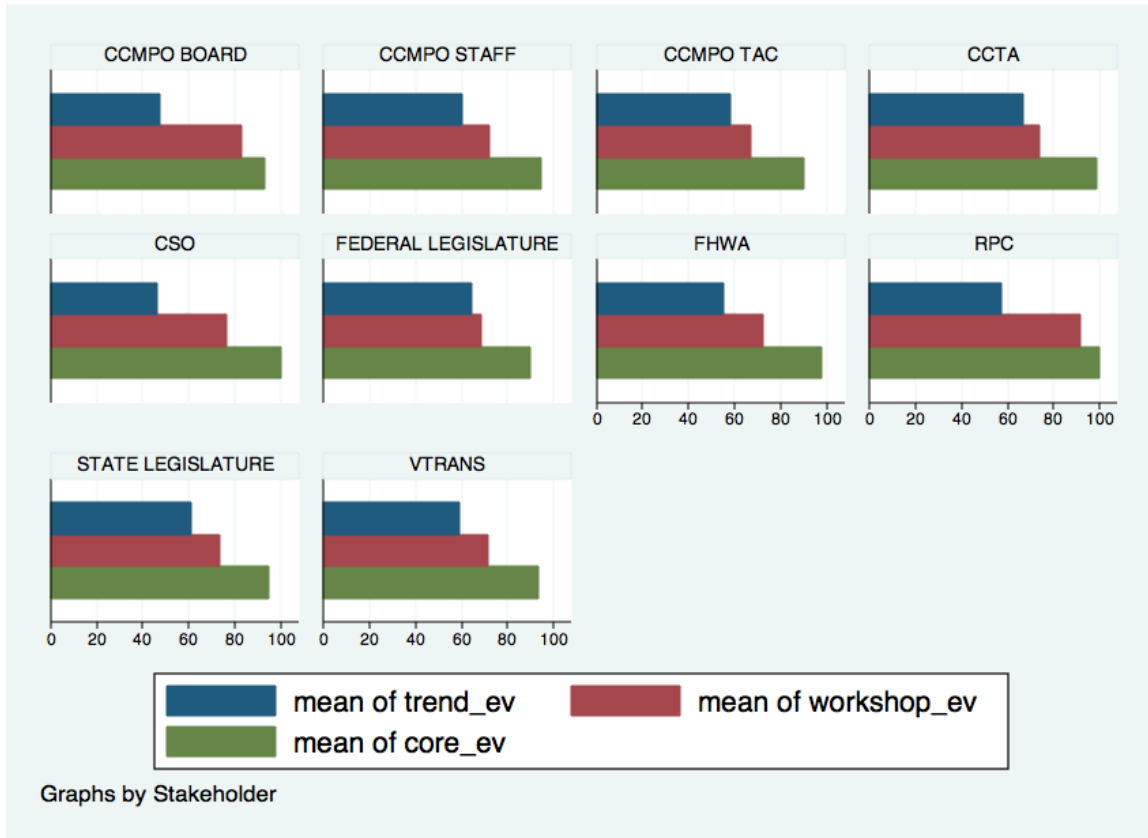
In general, a high level of correlation is found between the expected values for the three scenarios, as shown in Figure 3-6.

Figure 3-6: Correlations between the expected values for the three scenarios
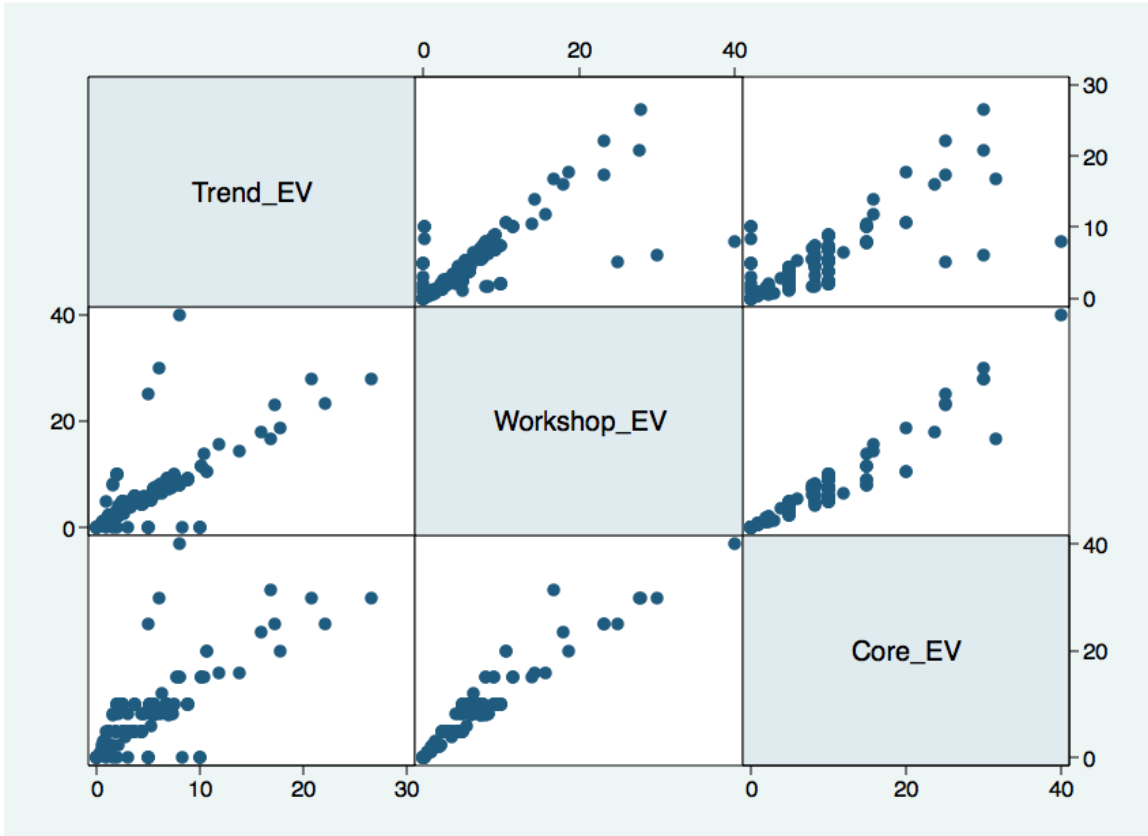
Figures 3-7-1 to 3-7-3, panels a, b and c, show the distribution of expected value for each of the three scenarios by each of the 12 decision criteria. In general, expected value distribution varies drastically across the sample pool of focus group participants.

Figure 3-7-1: Distribution of expected value for 2035/2060 MTP Scenarios by Decision Criteria: Panel (a): Trend Scenario

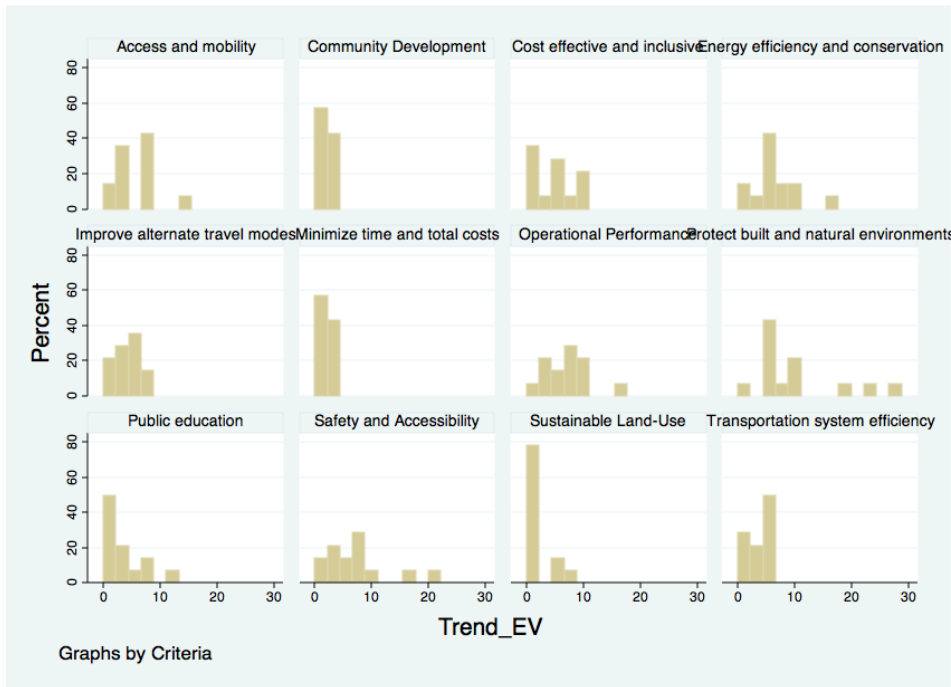**Figure 3-7-2: Distribution of expected value for 2035/2060 MTP Scenarios by Decision Criteria: Panel (b) Workshop Scenario**
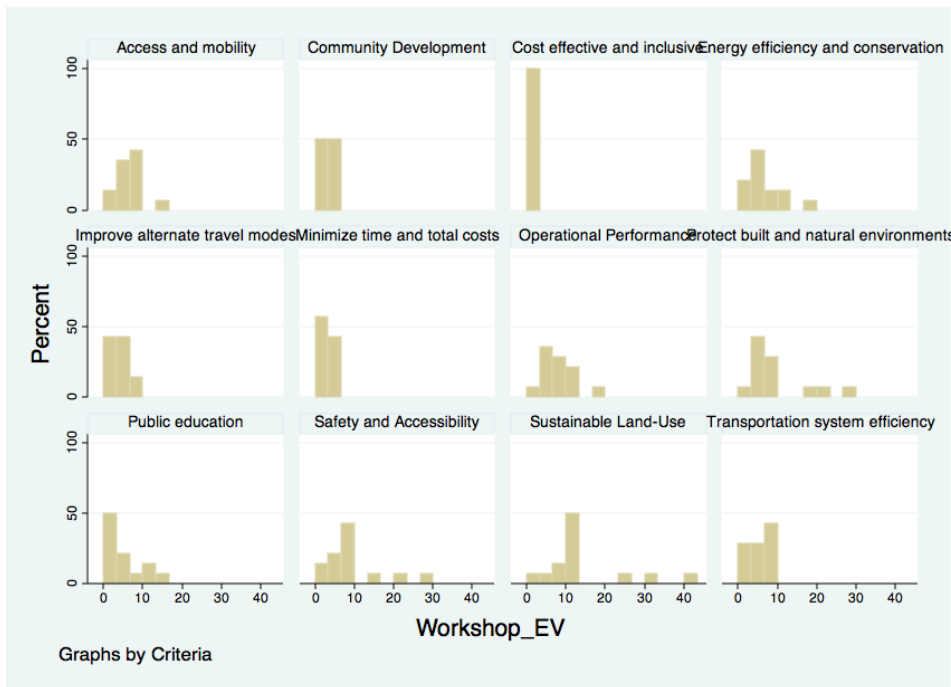
Figure 3-7-3: Distribution of expected value for 2035/2060 MTP Scenarios by Decision Criteria: Panel (c) Core Scenario
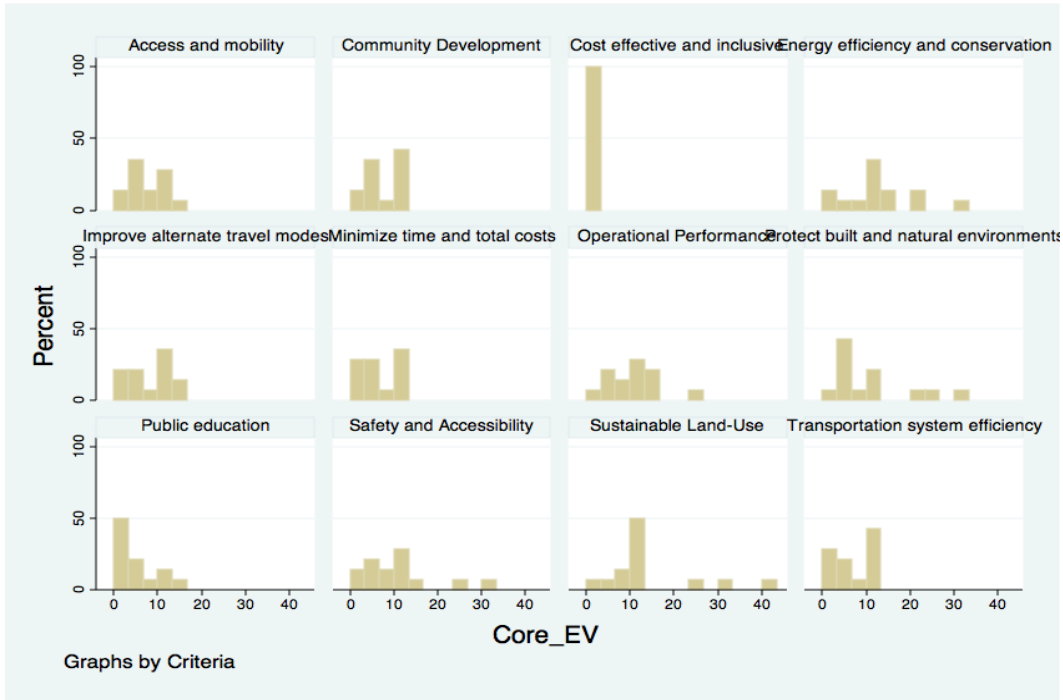

Graphs by Criteria

Table 3-3 below shows results from analysis of variance conducted to test for the null hypothesis of constant expected value variance between stakeholder groups for the three MTP scenarios. We reject the hypothesis of constant variance for following criteria: sustainable land-use; safety and accessibility; community development; access and mobility; and transportation system efficiency.

Table 3-3:Analysis of Variance Between Stakeholder Groups for Expected Value on 2035/2060 MTP Scenarios

Decision Criteria	Trend Scenario		Workshop Scenario		Core Scenario	
	SS (MS)	*F (Prob>F)*	*SS (MS)*	*F (Prob>F)*	*SS (MS)*	*F (Prob>F)*
1. Operational performance	170.48 (18.94)	2.42 (0.2043)	218.60 (24.28)	2.42 (0.2043)	373.82 (41.53)	2.42 (0.2043)
2. Sustainable land-Use	61.03 (6.78)	358.95*** (0.0000)	1501.61 (166.84)	358.95*** (0.0000)	1501.61 (166.84)	358.95*** (0.0000)
3. Safety and accessibility	407.34 (45.26)	12.77** (0.0129)	732.43 (81.38)	12.77** (0.0129)	851.52 (94.61)	12.77** (0.0129)
4. Minimize time and total costs	22.72 (2.52)	2.42 (0.2043)	58.17 (6.46)	2.42 (0.2043)	161.60 (17.95)	2.42 (0.2043)
5. Protect built and natural environs	647.80 (75.39)	3.82 (0.1049)	717.55 (79.72)	3.82 (0.10)	827.59 (91.95)	3.82 (0.10)
6. Community development	6.61 (0.73)	6.36** (0.0452)	26.46 (2.94)	6.36** (0.0452)	105.85 (7.39)	6.36** (0.0452)
7. Access and mobility	154.99 (17.16)	12.01** (0.0145)	166.85 (18.53)	12.01** (0.0145)	199.82 (22.20)	12.01** (0.0145)
8. Transportation system efficiency	51.97 (5.77)	5.77* (0.0533)	90.55 (10.06)	5.77* (0.0533)	168.38 (18.70)	5.77* (0.0533)
9. Energy efficiency and conservation	210.51 (23.39)	3.86 (0.1031)	210.51 (23.39)	3.86 (0.1031)	740.10 (82.23)	3.86 (0.10)
10. Improve alternate travel modes	65.47 (7.27)	3.66 (0.1120)	88.52 (9.83)	3.66 (0.1120)	243.94 (27.10)	3.66 (0.1120)
11. Public education	152.65 (16.96)	3.28 (0.1321)	271.38 (30.15)	3.28 (0.1321)	271.38 (30.15)	3.28 (0.13)
12. Cost effective and inclusive	144.45 (16.05)	2.06 (0.2533)	0.01 (0.001)	2.06 (0.2533)	.002 (.0001)	2.06 (0.2533)

4. Implications of the Findings

While MCDA clearly recommended core scenario as the scenario with highest expected value across almost all stakeholder groups, the implementation of this scenario will require overcoming serious challenges and governance issues. While the Trend scenario assumes that "current trends of the past 30 years [will] persist 50 years into the future," this scenario imposes minimal (if any) additional strictures upon existing zoning and development, and for that reason imposes the least prohibitive capital costs. However, "this type of development pattern… requires more spending on public services like roads, water, sewer, and emergency services which are more costly given the distances between houses/buildings as well as from town centers". In contrast, the **Workshop** scenario pivots on the concept of a "diffused centers pattern", which is intended to concentrate "urban sprawl" through mixed-use centers, the renovation and upkeep of existing urban structures, and "very limited development in rural areas". The workshop scenario addresses the overextension of public services by restricting growth to these diffuse centers, allowing public works to funnel federal funds into more concentrated areas, leading to higher quality development of those areas; such focused distribution of funding would likely defray capital costs incurred by bolstering public transit and renovating infrastructure. In addition, less square mileage is lost to fragmented centers of population (as in the Trend scenario), and land is used more efficiently as a result. Several challenges arise, however: first, existing zoning and development regulations may not be amenable to higher density development and would therefore need revision/appellation to allow for this diffused centers scenario; second, decreasing the amount of space into which the metropolitan area can expand will naturally increase the population density of that area.

The **Core** model seeks to impose a rather radical structure upon the future growth of Chittenden County by "locating 45% of all new households over the next 50 years into Burlington and another 5% in Winooski", with the aim of creating a dense, urban-style population center in Burlington. The advantages to such a model are many: municipal services are not overextended into rural areas and infrastructure can be maintained/upgraded in a more expedient manner; public transit, biking, and pedestrianism provide viable alternatives to automobile congestion; and rural areas are "relatively open" and undeveloped, preserving Vermont's natural resources. Under the core scenario, high density housing would require major alterations to current zoning and development regulations, and "may change the character of those municipalities" into which such concentrated growth would be funneled; additionally, the Core scenario represents a "dramatic reversal in historic trends", which could represent a high cost of imposition in the form of community opposition, redirection of capital funds away from suburban and rural areas, and which may necessitate major infrastructure overhauls.

Though MCDA clearly supports the core scenario as a planning template, the core scenario's radical departure from historical growth in the Burlington area could be an exceedingly hard sell to average Vermont residents, policymakers, and developers, all of whom would have to appreciably alter their present courses in order to realize such a model. On the other hand, the data clearly disfavor the trend scenario; so, by process of elimination, the alternative scenario best suited to compromise could very likely be the Workshop scenario in 25-35 year planning horizon. In many ways it is the lowest common denominator between an undesirable lack of change (Trend) and a prohibitively rapid imposition of change (Core); the Workshop scenario also has the benefits of a ready-made support network, having been proposed by the CCMPO 2009 survey groups, and tangible, potentially data-rich implementation in the form of completed multi-use facilities. Though it does not promote idealized benefits on par with the Core scenario or cost virtually nothing in the short term like the Trend scenario, the Workshop scenario eliminates the need for wholesale sweeping multi-departmental reform while reducing urban sprawl; moreover, it has an inherent

flexibility that would allow each diffuse center to retain its regional identity without compromising large landmasses to unfettered development or incurring massive public works costs. On the other hand, core scenario would reflect best the weighted judgment of stakeholder groups represented in the focus groups conducted for this study. CCMPO[25] is planning to release 2035 MTP in 2013 and it has two more years of public deliberation to continue to discuss the practical challenges in making a sound judgment. Further, it is recommended that the long term 2035 MTP must be explicitly linked with short term TIP and STIP processes, so short to medium term project prioritization could explicitly follow the vision agreed upon for long term 2035 MTP.

5. Conclusions

Using a "participatory action research" methodology, the research team intervened in transportation planning deliberations that are going on in CCMPO in terms of designing the 2060/2035 MTP. Through the use of a deliberative MCDA methodology in the specific context of eliciting value trade-off for a baseline and two alternative transportation planning scenarios, the research team evaluated and scored planning scenarios according to their impact functions and weights elicited from the participants of two focus groups implemented in September, 2010. Based on multi-criteria expected value scores estimated for stakeholder groups interviewed for this study, CCMPO is recommended to move forward with the core scenario for the 2035 MTP. Given the limited sample of stakeholder representation in the two focus groups, it is simultaneously recommended that additional multi-stakeholder focus groups and a survey study would enormously help CCMPO in eliciting broad citizen and policy maker evaluations according to the deliberative multi-criteria method presented in this study. Sensitivity analysis of impact functions is also warranted in a future study. Finally, the nature of connections between short- and long-term transportation planning practice needs to be further investigated and improved.

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Appendix A: Focus Group Agenda
Dates: September 24 and September 27, 2010
Venue: CCMPO Conference Room
110 West Canal Street, Suite 202, Winooski VT 05404

Time	Agenda Item
8:00-8:30 am	*Meet and Greet. Continental breakfast*
8:30-9:00 am	Introductions and overview of the focus group agenda
9:00-9:30 am	TIP Project Prioritization: history and current process
9:30-10:30 am	Scoring criteria and weights for assessing trade-offs among TIP Projects
10:30-10:45 am	*Coffee/Tea Break*
10:45-11:15	Identifying power and accountability dynamics in TIP project prioritization process
11:15-11:45	MTP Scenario Development: History and current process
11:45-12:30 pm	Criteria and weights for assessing trade-offs among MTP scenarios
12:30-1:30 pm	*Lunch*
1:30-2:15 pm	Identifying power and accountability dynamics in MTP scenario development process
2:15-3:00 pm	Connecting short/medium term (TIP) with long-term (MTP) integrated regional planning: current practices and issues
3:00-3:15 pm	*Coffee/Tea Break*
3:15-4:00 pm	Developing network structure for integrated regional planning
4:00-4:30 pm	Identifying power and accountability dynamics in the governance network structure
4:30-5:00 pm	Alternate network structures for navigating trade-offs in short/medium and long range integrated planning
5:00-5:30 pm	Open discussion, remaining issues, concluding remarks

Appendix B: Impact Functions for MTP Criteria for three scenarios

Criteria	Proxy	Trend Scenario	Workshop Scenario	Core Scenario	Trend_Norm	Workshop_Norm	Core_Norm
1. Operational Performance	Annual PM Peak Vehicle Hours of Delay	15.4	13.6	10.4	0.675324675	0.764705882	1
2. Sustainable Land Use	Land Consumed by Development (sq. miles)	124	25	25	0.201612903	1	1
3. Safety and Accessibility	Average Projected Congestion in 2035 (vehicle crashes/year)	2883	2150	1994	0.691640652	0.92744186	1
4. Minimize time and	Average commute time to work in 2035 (minutes/day)	40	25	15	0.375	0.6	1
5. Protect built and natural environment	Weekday Daily Greenhouse Gas Emissions (tons of CO_2)	3210	3050	2840	0.884735202	0.931147541	1
6. Community Development	Population Density (individuals per sq.mi) (539 sq. mi in CC)	394.961039	789.9220779	1579.844156	0.25	0.5	1
7. Access and mobility	Percent Daily Trip Possible by Public Transit	51%	53%	58%	0.879310345	0.913793103	1
8. Transportation system efficiency	Transportation $s invested per capita in 2035	198	150	110	0.555555556	0.733333333	1
9. Energy efficiency	Gallons of Oil needed per person per year in 2035	300	220	160	0.533333333	0.533333333	1
10. Improve alternate travel modes	Percent Daily Trips Made by Walking of Bicycling	4.30%	5.00%	8.30%	0.518072289	0.602409639	1
11. Public education	Civic responsibility (Constructed Scale from 1 to 10)	6	8	8	0.75	1	1
12. Cost effective and inclusive	Projected Budget Shortfall	1	116	261	1	0.00862069	0.00383142 !

Abbreviations, Acronyms, and Symbols

CCMPO Board- Chittenden County Metropolitan Planning Organization, Board
CCMPO Staff- Chittenden County Metropolitan Planning Organization, Staff
CCMPO TAC- Chittenden County Metropolitan Planning Organization, Transportation
Advisory Committee
CCMPO- Chittenden County Metropolitan Planning Organization
CCTA- Chittenden County Transportation Authority
CSOs- Civil Society Organizations
FHWA- Federal Highway Administration
MCDA- Multi Criteria Decision Analysis
MPO- Metropolitan Planning Organization
MTP- Metropolitan Transportation Plan
PI- Principal Investigator
RPC- Regional Planning Commission
US DOT- United States, Department of Transportation
VTRANS- Vermont Agency of Transportation
WTP- Willingness to Pay