Using Group Model Building for Analysing Environmental Conflict Management in the Wellington Transmission Gully Project

Arun A. Elias[1], Robert Y. Cavana[2] and Laurie S. Jackson[3]
[1&2] Victoria Management School, Victoria University of Wellington
[2] Environmental Studies, Victoria University of Wellington
P.O. Box 600, Wellington, New Zealand
Telephone: +64-4-463 5736[1], +64-4-463 5137[2], +64-4-463 5461[3]
Email: Arun.Elias@vuw.ac.nz Bob.Cavana@vuw.ac.nz Laurie.Jackson@vuw.ac.nz

Abstract: Developing a shared mental model of stakeholders in conflict is a challenge in environmental conflict management. In this paper, we present a shared mental model of stakeholders in environmental conflict in the Transmission Gully project, a large scale transport infrastructure project in the Wellington region, New Zealand. The shared mental model and analysis are based on system dynamics and use the principles of qualitative group model building. Selected stakeholders of this project generated a shared mental model, in the form of a causal loop diagram. Behaviour over time charts for the main variables are also developed and analysed qualitatively to provide different insights into potential system behaviours. The causal loop model presented in this research has also been used as the basis for the development of a system dynamics model.

Keywords: Group Model Building, Stakeholders, Environmental Conflict, System Dynamics, Systems Thinking, Transmission Gully project

1. Introduction

Building models directly with client groups has become increasingly common in the field of system dynamics (Andersen and Richardson, 1997). This has resulted in an increasing research interest on group model building exercises based on system dynamics. Researchers like Vennix (1996) used group model building where team members exchange the perceptions of a problem and explored such questions as: what exactly is the problem we face? How did the problematic situation originate? What might be its underlying causes? How can the problem be effectively tackled?

Group model building was successfully applied in many areas. Some interesting examples of application include management of housing associations (Etienne et al., 1999), system conceptualization in an oil refinery (Hwang and Hu, 1999), quality in health services (Cavana et al., 1999) and fleet management (Vennix, 1996). Insights gained from most of these exercises point to the usefulness of group model building in developing a shared mental model of stakeholders involved.

Developing a shared mental model of stakeholders can be very helpful while managing environmental conflicts. According to the US government's environmental policy and conflict resolution statute of 1998, the term environmental conflict (dispute) is defined as a dispute or conflict relating to the environment, public lands, or natural resources. Jackson (1997) explains about three different types of environmental conflict. Conflict can exists between different users of a resource. It can exist between the users of a resource and those who would conserve it. Conflict also exists between decision-makers and those who want more of a say in those decisions. In this research, a group model building exercise was conducted, by bringing together various stakeholders, as explained in Jackson's classification given above like different users, environmentalists, decision makers and other important stakeholders of the proposed Transmission Gully motorway project.

In this paper, we present a group model building exercise that was used to generate a shared mental model of selected stakeholders in an environmental conflict. We start by presenting the background to the conflict situation – a large-scale transport infrastructure project called Transmission Gully in the Wellington region in New Zealand. Then, the different steps of the group model building exercise as applied to the project are presented based on the methodology outlined in Maani and Cavana (2000). Further, the causal loop model generated though this group model building is analysed in terms of the feedback loops formed in the model.

2. Background to the Transmission Gully Project

The Wellington Regional Council managed the project that we used in this study. The Wellington Regional Council had been seeking a suitable solution to the increasing problems of congestion, safety and community severance along the existing State highway route between Paremata and Paekakariki. A possible solution to these problems was the construction of the Transmission Gully motorway, a 27-km inland route. The vision of the Wellington Regional Transport strategy, as explained in the Wellington Regional Land Transport Strategy, 1999 –2004 (Wellington Regional Council, 1999) was 'A balanced and suitable land transport system that meets the needs of the regional community', and it in turn demands, the proposed Transmission Gully motorway to be environmentally and economically sustainable.

The cost of constructing Transmission Gully was estimated to be NZ$245 million. At present, government funding alone might not meet this cost. This situation suggested the introduction of road pricing. Thus, if the early construction of Transmission Gully became a reality, it was likely to be the first application of road pricing in New Zealand and the principle of 'doing it right the first time' became relevant in this case. Due to the importance of this situation, the Wellington Regional Council started a project to explore the different aspects of road pricing.

The case of the Transmission Gully project presented an interesting example of environmental conflict. This study found that the idea of the Transmission Gully project was conceived as early as 1915. Later in 1940, the US army, camped at Queen Elizabeth Park during World War II, found the present highway insecure and proposed an alternate route through the Transmission Gully. The American government offered to fully fund the project, but due to political reasons, the New Zealand government rejected the offer. Our identification of the milestones of this project during the last 88 years, revealed the importance of such stakeholder behaviour that resulted in the delay of this project.

After 88 years since its birth, the Transmission Gully project still made occasional headlines in the New Zealand media. The conflict between different stakeholders that kept on surfacing, presented increasing challenges to the transport planning managers of the Wellington Regional Council. This complex situation faced by the managers of large-scale development projects in public arena like the Transmission Gully could ease, if they used the available ‘systems thinking’ frameworks to develop and analyse shared mental models of stakeholders.

3. Qualitative Group Model Building

Among the different methods available for group model building, the method used in this paper is based on the systems thinking methods outlined in Cavana et al. (1999) and Maani and Cavana (2000). In this qualitative group model building approach, hexagons are used for systems thinking. For this research, four steps of group model building were used:

Step 1: Hexagon generation
Step 2: Cluster formation
Step 3: Variable identification and
Step 4: Causal loop development

Maani and Cavana (2000) have explained this procedure systematically in their Systems Thinking and Modelling methodology, based on Hodgson’s (1994) use of hexagons for issue conceptualisation and Kreutzer’s FASTbreakTM process (1995) for using hexagons to develop causal loop diagrams.

Step 1: Hexagon Generation

This step consists of generating hexagons for each issue, opportunity or obstacle identified by the stakeholders. To help the stakeholders in generating hexagons, an organising question was used in the first group model building session. The organising question was:

‘What are the factors that should be considered while deciding whether the Transmission Gully project should go ahead or not?’

Coloured hexagons were used as a facilitation tool. Yellow hexagons were used for recording ordinary issues, opportunities or obstacles identified by the participants. Pink hexagons were used when they generated a strongly held/felt issue, opportunity or obstacle.

The stakeholders who attended the session generated a total of 93 hexagons. Some of these hexagons are presented in Figure 1.

Step 2: Cluster Formation

As the second step, the stakeholders identified hexagons that have something in common. These hexagons were grouped together to form clusters and a descriptive name was given to each cluster. In the workshop, the stakeholders made 18 such clusters. The descriptive names given to each of these 18 clusters include: Treaty issues, physical environment, consequential traffic, needs, distribution of costs and benefits, money, regional strategic issues, alternative modes, political issues, quality of life, hazards, alternative routes methodology, practicality, regional economic development, energy, Kapiti sustainability and social & community issues. Two of these clusters are presented in Figure 2.

Step 3: Variable Identification

In the next session, the stakeholders identified a few variables associated with each cluster. Blue hexagons were used to represent the variables. These variables are presented in Table 1.

Step 4: Causal Loop Development

In this session, stakeholders tried to establish the links between variables. They first identified two variables that were related and provided a directed arrow between each pair of related variables. To generate a directed arrow, they placed a positive (+) sign near the head of the arrow if an increase (or decrease) in a variable at the tail of an arrow caused a corresponding increase (or decrease) in a variable at the head of the arrow. If an increase in the causal variable caused a decrease in the affected variable, a negative (-) sign was placed near the head of the arrow. An initial version of the causal loop diagram was thus developed. It is shown in Figure 3.

A broad analysis of this causal loop diagram can be done by identifying the main sectors and loops present in this diagram. As far as the sectors are concerned, stakeholders identified traffic sector, environmental sector, community sector and economic sector interacting in this system. A closer look at this diagram also reveals some important feedback loops.

In the traffic sector, stakeholders were able to generate a feedback loop connecting average number of trips per person per day, travel time, community demands, political will, Transmission Gully construction and change in trip volume& distribution. Analysing the links show that this is a reinforcing loop.

The second loop connects average number of trips, local air quality, global air quality, position of environmental stakeholders, political will, TG construction and change in trip volume & distribution. Variations of this loop can be formed by taking a route via regional energy consumption per trip and total regional transport energy instead of local air quality and global air quality. In this sector few other loops were also generated by connecting TG construction, biodiversity or land take, position of environmental stakeholders and political will. Analysing the links show that all these are balancing loops.

The stakeholders were able to form another loop by connecting average number of trips per person per day, number & severity of accidents, number of days the road is closed due to hazards, social impact on community, community demands, political will, TG construction and change in trip volume & distribution. Analysing the links show that this is a reinforcing loop.

In the economic side, a loop connecting average number of trips per person per day, travel time, regional economic cost of congestion, regional GDP, position of economic stakeholders, political will, TG construction and change in trip volume & distribution was generated. Analysing the links show that this is balancing loop.

A detailed analysis of this causal loop diagram was not done since this was only an initial version. Nevertheless, this diagram gave a fair idea about the mental models shared by the stakeholders regarding the Transmission Gully project. Later, this model was refined to develop a more meaningful causal loop model of this system.

4. Modified Causal Loop Model

After developing an initial version of the causal loop model, the model can then be refined and the reinforcing and balancing loops identified (Maani and Cavana, 2000). In this research, the modeller refined the initial casual loop model made by the stakeholders. The modeller took two considerations at this stage. First, the scope of the model was narrowed down to include the positions and interests of environmental and community stakeholders only. So, the variables relating to the positions and interest of economic stakeholders were not considered in this model. Second, consideration was also given towards the development of a dynamic model at a later stage of this research. It was aimed that, all or most of the variables and linkages present in the modified causal loop model could be used in the dynamic model.

Also, the system dynamics literature was reviewed to identify similar models during the modification of the causal loop diagram. This review found the causal loop model on traffic congestion by Sterman (2000) quite helpful in making sense of the initial causal loop diagram and in modifying it. The modified causal loop model is presented in Figure 4.

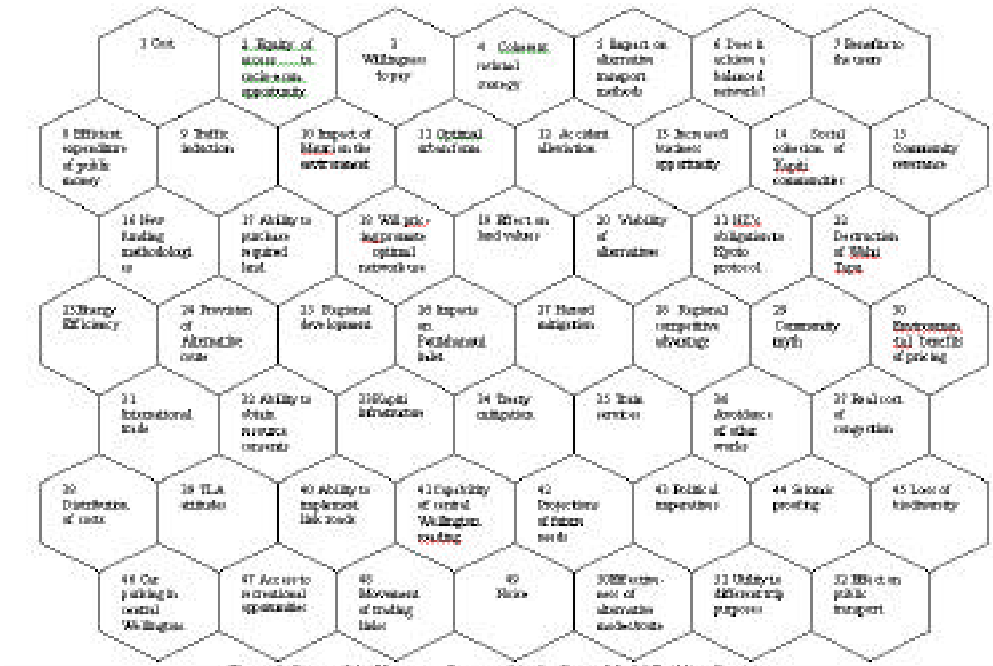


Figure 1. Some of the Hexagons Generated in the Group Model Building Session

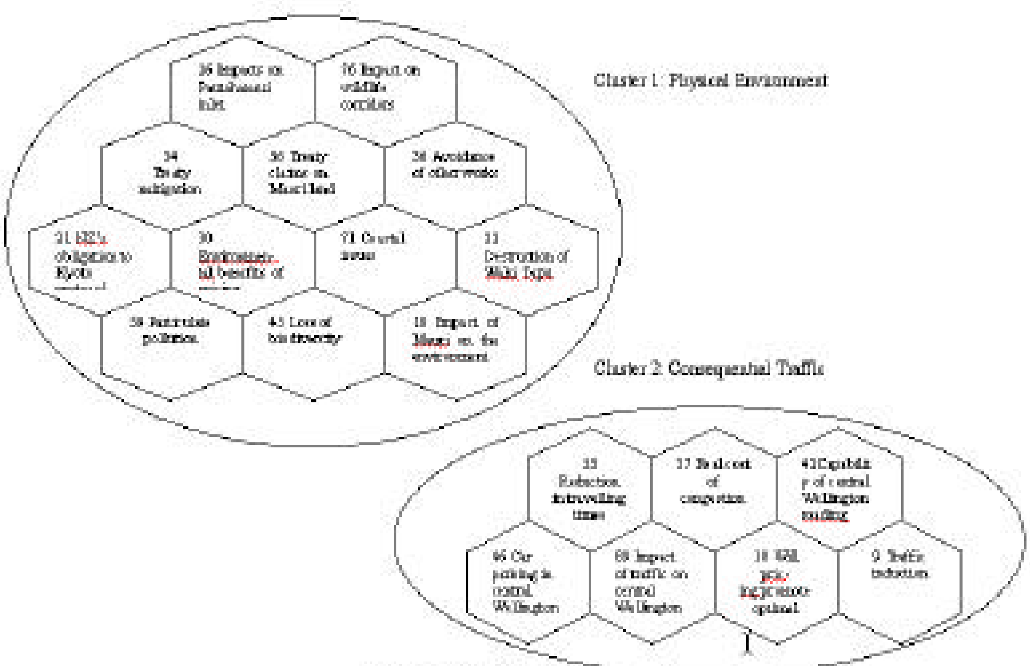


Figure 2. Examples of Clusters

Cluster	Variable
Hazards	1. Hazard Cost Index
	2. Number of days that the Road is Closed due to Hazards p.a.
Alternative routes	3. Perceived Effectiveness of Alternative Routes
	4. Actual Effectiveness of Alternative Routes
Methodology	5. Goals
	6. Benefit Cost Ratio
Physical Environment	7. Water Quality Index
	8. Local Air Quality
	9. Global Air Quality
	10. Land Take
	11. Biodiversity
Distribution of Costs & Benefits	12. Distribution of Economic Costs
	13. Distribution of Economic Benefits
Money	14. Cost of each Alternative
	15. Allocation of Costs
Alternative Modes	16. Actual Effectiveness of Alternative Modes
	17. Perceived Effectiveness of Alternative Modes
	18. Number of Passenger Kilometres p.a.
Kapiti Sustainability	19. Kapiti Sustainability
Social and Community Issues	20. Social Impact on Community
	21. Number of and Severity of Accidents p.a.
Treaty Issues	22. Comparative Compliance Cost of Treaty Obligations
Consequential Traffic	23. Change in Trip Volume and Distribution
Needs	24. Population
	25. Average Number of Trips per Person per day
Energy	26. Regional Energy Consumption per trip
	27. Total Regional Transport Energy Consumption
Regional Economic development	28. Regional GDP
	29. Regional Economic Cost of Congestion
	30. Travel Time
Political Issues	31. Political Will
	32. Community Demands
Quality of Life	33. Quality of Life Index
	34. Hanson’s Accessibility Index
Regional Strategic Issues	35. Public Perception of Regional Land Transport Strategy

Note: The participants felt that no variables were required for the cluster ’practicality’.

Table 1. Variables identified by the Group Model Building Participants

5. Reference Mode

One of the tools of systems thinking is behaviour over time (BOT), which is also referred to as 'reference mode behaviour'. BOT shows the pattern of a variable over an extended period, typically several months to several years. This pattern can indicate the variations and trends in the variable of interest – for example growth, decline, oscillations or a combination thereof. In BOT graphs, the horizontal axis represents time and the vertical axis represents the performance measure of interest. The important elements of BOT are the overall directions and variations, not the numerical value of the variable. Therefore, BOT graphs are usually drawn in a rough sense without exact numerical values attached (Maani and Cavana, 2000).

For developing a reference mode for this research, five variables were used. These variables are traffic volume, travel time, speed, attractiveness of driving and CO_2 emissions. Analysing the data since 1980 from the Wellington Regional Council for 7 to 9 am travel between McKay's crossing and Linden, it was seen that the traffic volume, travel time and CO_2 emissions were increasing steadily. It was also seen that the speed of travel and the attractiveness to driving was decreasing. This behaviour is shown in Figure 5.

6. Analysis of the Causal loop diagram

The casual loop model was analysed by identifying the feedback loops formed in the model. Feedback loops can be reinforcing or balancing. The feedback loops identified in this model include two reinforcing and seven balancing ones.

Reinforcing loops are positive feedback systems. They can represent growing or declining actions. Unlike reinforcing loops, balancing loops (negative feedback systems) seeks stability or return to control (Maani and Cavana, 2000). The analysis of the seven feedback loops is discussed below:

Loop 1. Constructing Transmission Gully Loop (B_1)

A possible starting point to this causal loop analysis is the variable, traffic volume. In linear thinking, traffic volume is the problem and building new roads is the solution (Sterman, 2000). According to the 'Constructing Transmission Gully Loop', when traffic volume increases, the volume-capacity ratio increases. An increase in volume-capacity ratio will decrease the speed of travel, which in turn increases the travel time. When travel time is more, the community demand for building the Transmission Gully motorway will increase, strengthening the political will for the Transmission Gully construction. Because of this increased political will, if the Transmission Gully becomes a reality, then there will be more highway capacity which in turn will reduce the volume-capacity ratio.

Thus 'constructing Transmission Gully' is a balancing feedback loop. The objective of the loop, desired travel time is shown explicitly in the model for clarity. If this were the only loop operating in the system, it would achieve its objective, i.e. when travel time is more, build new roads like the Transmission Gully motorway, so that travel time decreases towards the desired level. But, this is not the only loop operating in the system and it is worth looking at the other feedback loops to get a better understanding of the system.

Loop 2. Purchasing Cars Loop (B_2)

The second loop operating in the system explains the behaviour of people, when there is a decrease in travel time, due to the construction of new roads. When travel time decreases, there will be an increased attractiveness towards driving cars. When attractiveness to driving is more, people will avoid other modes of travel and this eventually results in an increasing number of car purchases. This increases the total number of cars in the region. When the number of cars in the region increases the traffic volume increases. An increase in travel time will result in an increasing volume-capacity ratio and decreasing speed. This, in turn, will increase the travel time.

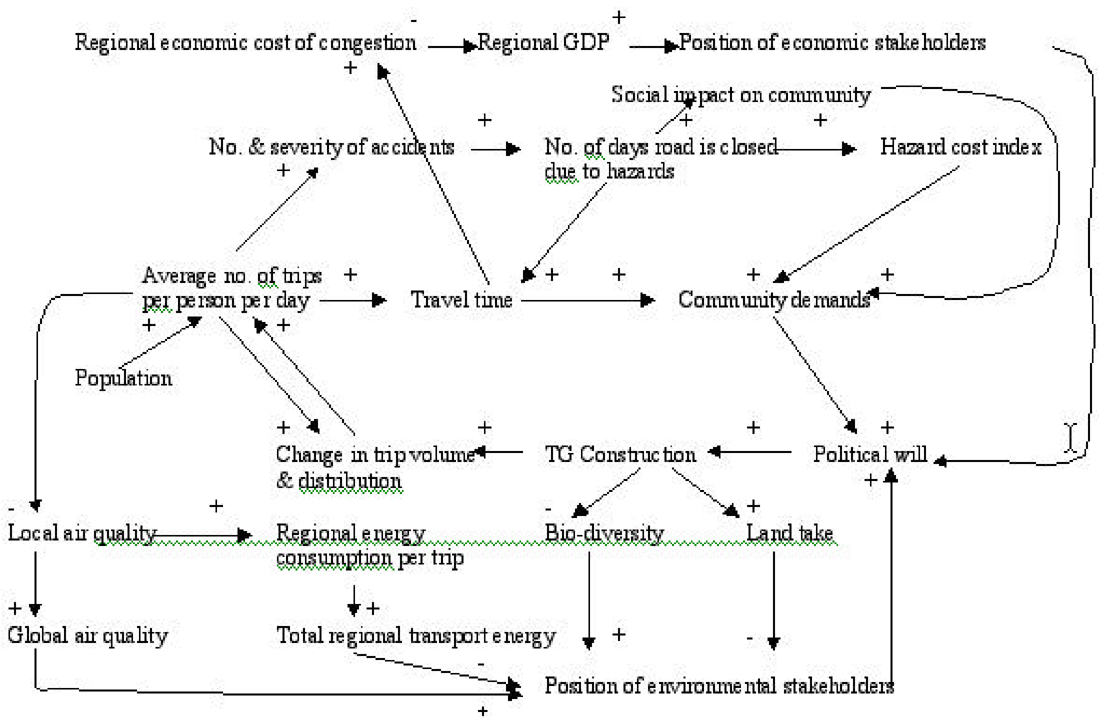


Figure 3. Initial Causal Loop Diagram

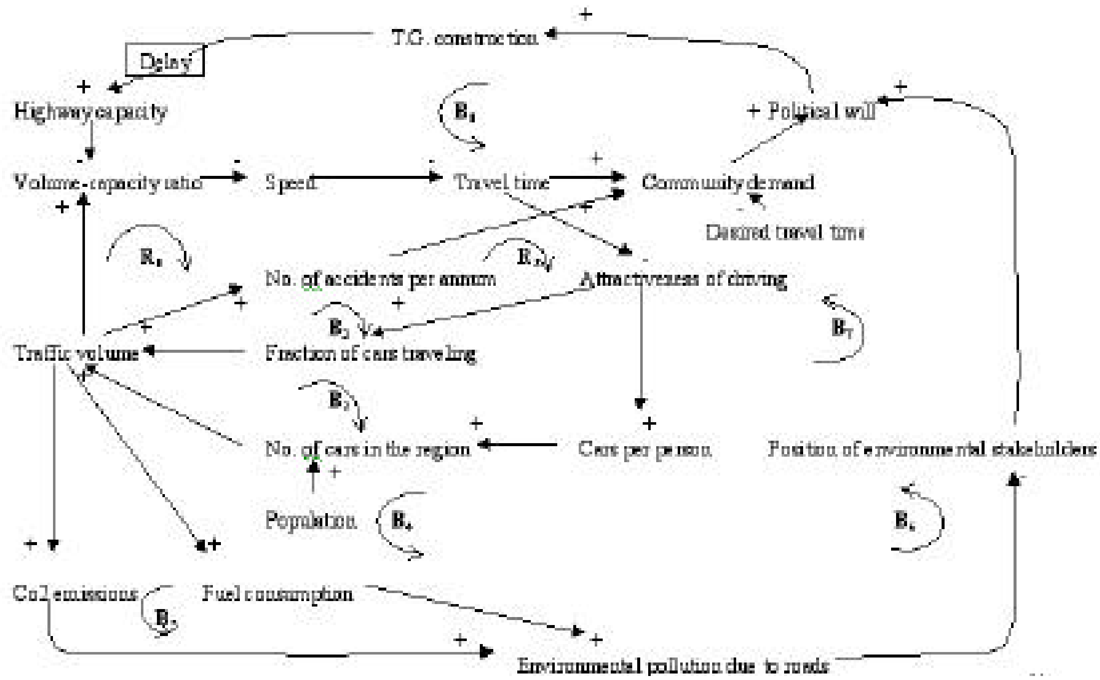
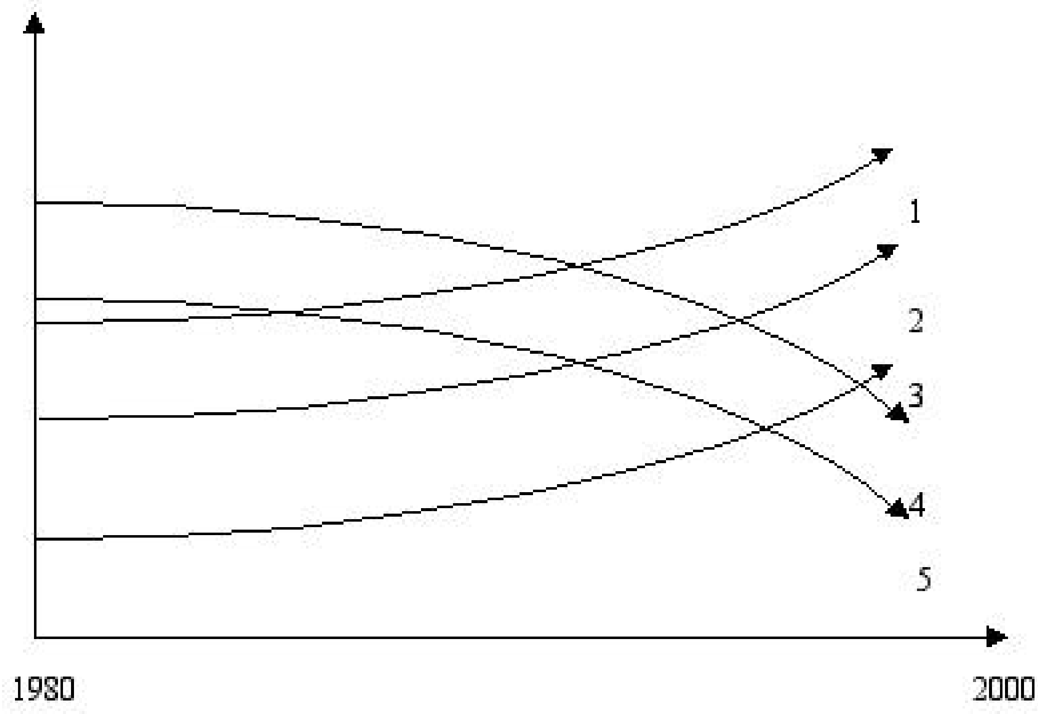


Figure 4. Modified Causal Loop Model



1=Traffic volume, 2= Travel time, 3=CO_2 emissions, 4= Speed, 5 = Attractiveness of driving

Figure 5. Reference Mode

So, purchasing cars loop is a negative feedback (balancing) loop resulting in an increased travel time due to an increasing attractiveness of driving and increasing number of cars in the region. Population is considered as an exogenous variable here and it can be used to calculate the number of cars in the region, by multiplying it with cars per person. To summarise, the effect of this loop is to increase the travel time, negating the effect of decreasing travel time, achieved by the constructing Transmission Gully loop.

Loop 3. Travelling Cars Loop (B_3)

The third loop is quite similar to the second loop. When travel time decreases, the attractiveness of driving cars increases. This will result in more cars travelling on the road and that in turn will increase the traffic volume and volume-capacity ratio. When volume-capacity ratio is higher, the speed decreases, increasing the travel time.

Like the purchasing cars loop, the travelling cars loop is again a balancing loop. The effect of this loop is to increase the travel time due to an increase in the number of cars travelling on the road. Thus, both purchasing cars loop and travelling cars loop try to increase travel time, thereby negating the effect of the constructing Transmission Gully loop.

Loop 4. Community Purchasing Accidents Loop (R_1)

The fourth and fifth loops operating in the system explains some of the long-term effects of the Transmission Gully construction on the community. The intention of community stakeholders, when they put pressure on the politicians to build the new road is to decrease congestion. The constructing Transmission Gully loop (B1) explained how travel time initially decreased due to the construction of the Transmission Gully motorway whereas ‘Community Purchasing Accidents’ loop explains the behaviour of number of accidents occurring on the roads.

When traffic volume is more, the number of accidents in the road will be more. Due to this, the community will increase their demand for constructing the Transmission Gully, which will increase the political will and the chances of building the Transmission Gully motorway. If the Transmission Gully motorway is constructed, it will increase the highway capacity and decrease the volume-capacity ratio, thereby increasing speed and deceasing travel time. A reduction of travel time will increase the attractiveness of driving. An increasing attractiveness of driving cars will result in people purchasing more cars, increasing the total number of cars in the region. This will increase the traffic volume and the number of accidents on the roads.

The community purchasing accidents loop is, thus a reinforcing loop. It shows how the number of accidents keeps on increasing due to an increasing traffic volume. It also shows that, although the Transmission Gully motorway initially results in decreasing congestion, it also results in an unexpected side effect of increasing accidents.

Loop 5. Accidents while Community Travelling Loop (R_2)

This loop is similar to the ‘Community Purchasing Accidents’ loop (R_1). An increase in traffic volume can result in an increase in the number of accidents on roads. This may result in the construction of the Transmission Gully motorway due to increasing community demand and political will. This will result in increased highway capacity, reduced volume-capacity ratio and increased speed. Increased speed will reduce the travel time and reduction in travel time will increase the attractiveness of driving. This in turn will increase the fraction of cars traveling and thus the traffic volume. An increase in traffic volume tends to increase the number of accidents on roads.

Like the community purchasing accidents loop, accidents while community travelling loop is another positive feedback (reinforcing) loop. The community purchasing accidents loop showed the behaviour of number of accidents while following the purchasing cars loop (B_2). 'Accidents while Community Travelling' loop shows the behaviour of number of accidents while following the 'Travelling Cars' loop (B_3). Both these loops show how the number of accidents keeps on increasing due to an increasing traffic volume.

Loop 6. Fuelling Environmental Pollution Loop (B_4).

The sixth and the seventh loop operating in the system links the effect of traffic variables with environmental pollution and the subsequent behaviour of environmental stakeholders. According to the fuelling environmental pollution loop, an increasing traffic volume increases the amount of fuel consumption, contributing to an increasing pollution of environment due to roads. This increases the concern of environmental stakeholders towards the construction of new roads like Transmission Gully, which in turn decreases the political will to build Transmission Gully. If Transmission Gully is not built, the highway capacity will not increase and the volume capacity ratio will rise. This will reduce the speed and increase the travel time. An increasing travel time will reduce the attractiveness of driving which in turn reduces the cars per person and the total number of cars in the region. This will reduce the traffic volume and also the amount of fuel consumption.

The fuelling environmental pollution loop is a balancing loop. Based on this loop, the environmental stakeholders opposed the construction of new roads due to increasing fuel consumption. The fuelling environmental pollution loop explains how this reaction enables them to control the amount of fuel consumption.

Loop 7. Polluting CO_2 Loop (B_5)

The seventh loop, polluting CO_2 is similar to the fuelling environmental pollution loop (B_4). When the traffic volume increases the CO_2 emissions increases, thereby increasing the pollution of environment due to roads. This affects the position of environmental stakeholders negatively, towards the construction of new roads like Transmission Gully. When the opposition towards the Transmission Gully motorway increases, the political will to build it will go down. If the Transmission Gully motorway is not built, the highway capacity will not increase but the volume-capacity ratio will increase. This results in the reduction of speed and increased travel time. When the travel time is more, the attractiveness of driving will be less, which in turn reduces the cars per person and the total number of cars in the region. This will result in the lesser traffic volume and reduced CO_2 emissions.

'Polluting CO_2' loop is again a balancing loop and it affect the system in a similar fashion as the fuelling environmental pollution loop**.** This loop explains how the opposing position of environmental stakeholders towards construction of new roads like Transmission Gully enables them to control the amount of CO_2 emission.

Loop 8. Travelling Cars Consuming Fuel Loop (B6).

Travelling cars consuming fuel loop is quite similar to the fuelling environmental pollution loop (B_4). The main difference is in the links from the variable, attractiveness to driving. Travelling cars consuming fuel loop takes a route from attractiveness of driving via fraction of cars travelling to traffic volume. Fuelling environmental pollution loop takes a route from attractiveness to driving via cars per person and number of cars in the region to reach traffic volume. The effect of both the loops are similar. It is a balancing loop and explains how this reaction of environmental stakeholders enables them to control the amount of fuel consumption.

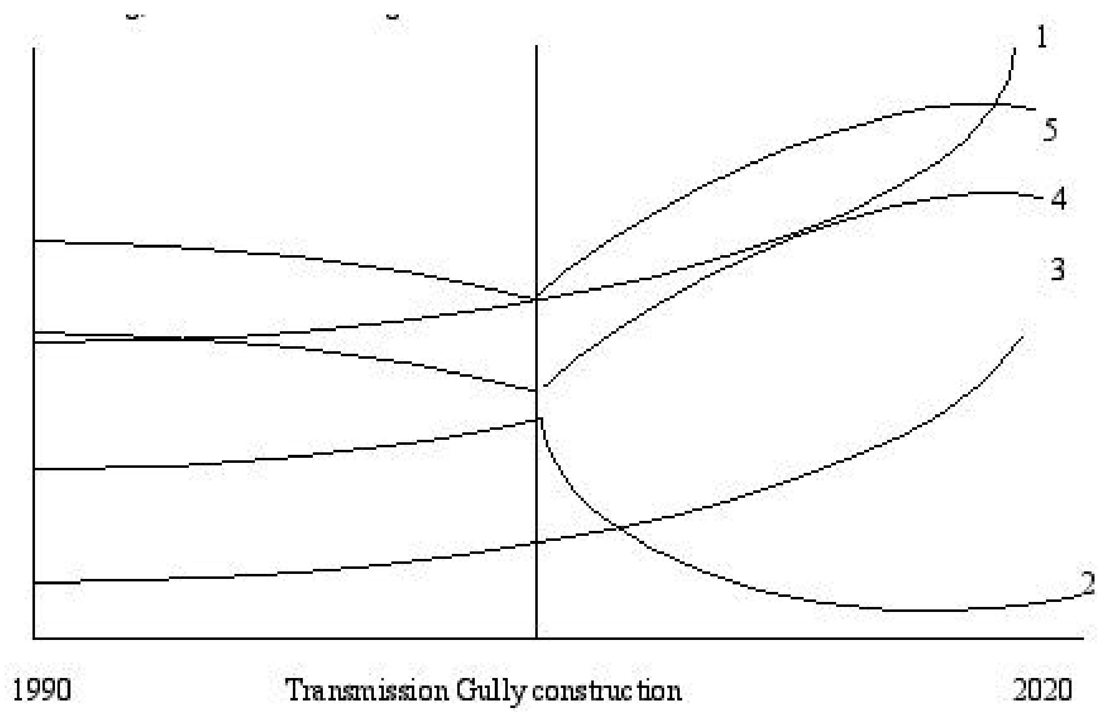
Loop 9. Travelling Cars Emitting CO_2 Loop (B_7)

Travelling cars emitting CO_2 loop is quite similar to the polluting CO_2 loop (B_5). Again, the main difference is in the connections from the variable, attractiveness to driving. The travelling cars emitting CO_2 loop takes a route from attractiveness of driving via fraction of cars travelling to traffic volume whereas fuelling environmental pollution loop takes a route from attractiveness to driving via cars per person and number of cars in the region to reach traffic volume. The effect of both the loops are similar. It is a balancing loop and explains how the reaction of environmental stakeholders enables them to control the amount of fuel consumption.

7. Loop Behaviour Over Time

Based on the causal loop diagram, behaviour over time chart was developed to understand the behaviour of some of the main variables over time. In the y-axis the time horizon was divided into two parts. The first part explains the behaviour of variables before Transmission Gully construction and the second part explains the behaviour of these variables if Transmission Gully is built. This behaviour over time chart is presented in Figure 6, with an approximate future time of 2020.

Based on the casual loop analysis, the travel time will keep on increasing till transmission gully is constructed and ready to use. Travel time will come down once vehicles start using this additional road. But after some time, travel time will start increasing due to an increasing number of cars on the road. Traffic volume will keep on increasing before and after the construction of transmission gully. The amount of CO_2 emission will behave in a similar way as the traffic volume. Speed will keep on decreasing till transmission gully is ready to use. Then it will increase for some time, but at some later point of time, it will start decreasing. The attractiveness of driving will also behave in a similar fashion like the speed, first it will decrease, then it will increase and after some time, it will start decreasing, due to an increasing travel time.



1=Traffic volume, 2= Travel time, 3=CO_2 emissions, 4= Speed, 5 = Attractiveness of driving

Figure 6. Behaviour Over Time Chart with Transmission Gully Constructed

8. Conclusion

System dynamics tools are often used to develop an explicit shared model of a complex system amongst a group (Maani and Cavana, 2000). This paper gave an illustration on how group model building was used in developing a shared mental model of stakeholders in the proposed Transmission Gully transport infrastructure project in Wellington, New Zealand. This group model building exercise showed that the hexagon process could be effectively used to generate an initial version of a causal loop diagram. This initial version was further refined to generate a modified casual loop diagram and was analysed in terms of the feedback loops formed.

Based on the feedback loops, behaviour over time charts were developed. The behaviour over time charts gave the indication that, presently variables like traffic volume, travel time and CO_2 emissions are increasing, while other variables like speed and attractiveness to driving are decreasing. It also showed that, it the Transmission Gully becomes a reality, travel time will initially decrease but after some time, it will slowly start increasing. Also, traffic volume and CO2 emissions will keep on increasing even after Transmission Gully is built. Further, variables like attractiveness to driving and speed will increase initially, once the Transmission Gully was built, but after a certain period of time, they will slowly start decreasing.

In summary, group model building was found useful in this research, for revealing the various interests of stakeholders in this environmental conflict situation. It helped the stakeholders to generate a shared mental model using the hexagon process. Finally, the causal loop model that was developed, has given a solid basis to build a dynamic model of the system.

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