Using Scripts for the Construction of Management Simulation Models in the Context of Multi-Agency Engagement

David Carter, Jonathan Moizer, and Shaofeng Liu

***Abstract*—For a solo researcher barriers have existed in how group model building scripts can be easily facilitated for those participating from multiple agencies to engage in producing convincing models. Overcoming these barriers enables System Dynamics to reach prospective beneficiaries who may not have considered modelling as a means of addressing dynamically complex, multi-faceted issues that are widespread in community healthcare. This paper aims to improve script selection, achieving effective results for participants involved in validating multi-agent, policy alternatives. By studying targeted elicitation techniques from system dynamics and elsewhere, it is possible to shed light on how learning from scripts for modelling in system dynamics can inform other problem structuring methods for engaging management decision makers.**

***Index Terms*—Group model building, scripts pilot, multi-agency engagement.**

I. Introduction

Failure to agree suitable scripts from a list of descriptions provided in versions of Scriptapedia [1] with gatekeepers spanning health and education agencies, indicated the need for an improved approach to multi-phased model construction for an emerging process. Gatekeeper unfamiliarity in selecting scripts, combined with script facilitation in practice by the principal researcher, were both contributing factors. Alongside such needs, the research faced elevated risk associated with combining modeler/ facilitator/ recorder roles within workshops and reducing this was considered paramount for research project success. The purpose of the case study is therefore to decide the best approach for synthesizing sympathetic interventions in child and adolescent mental health through existing providers and managers located in a large, English urban unitary authority. Specifically, the goals of modelling the case study include capturing comprehensive decision drivers alongside those deciding resource allocations from contributing agencies and investigating the mechanisms by which policy ambitions can be realized. The gap in knowledge is then used to support negotiation and agreement on how to best intervene in the system to reduce anxiety for those aged 11 when transferring between primary (elementary) and secondary (high) schools in the UK.

The aim of this paper is to determine which Group Model building (GMB) scripts to employ and in what sequence to meet the constraints of minimum meeting time for maximum commitment from a multi-agency combine to ensure efficiency and effectiveness across the emerging system. Objectives for this research include a comprehensive description of a pilot-based GMB approach, decomposing results from piloting selected scripts and then formulating a compressed approach for audience-focused GMB workshops.

A broad range of scripts have already been catalogued but only some would be suitable for GMB to inform construction of a fully quantified system dynamics model [2]. Not only is the GMB process shortened to the time constraints of those contributing, as a solo investigator the researcher has to collate model data at the same time as facilitating participants and capturing results. Some scripts lend themselves to less facilitation and recording effort, for example when individuals write their own views on paper for comment by others or participants that self-cluster individual sticky-notes on a whiteboard under themes that can be captured as a photograph. Others require full facilitation though a shared model-capture process. Piloting script selections is therefore important to ensure maximum audience engagement before commencing model construction with a representative audience. This piloting approach is designed to gauge likelihood of model production success based on the response of professionals without prior knowledge of modelling but with a proven ability to reflect upon identified parts of the system.

The remainder of the paper is organized as follows. The next section reviews related literature in decision conferencing and group model building theories of modelling. The approach to script selection research is discussed in Section III Methodology. Section IV presents and discusses some initial results resulting from the case study, followed by Conclusions and recommendations on what to use then follow in Section V.

II. Literature Review

There has been a growing number of publications in GMB and the utilization of scripts to facilitate GMB. A new multi-method survey tool [3] is adopted to evaluate participant views on specific GMB contributions to model construction. This enables scripts (including those beyond standard formatting offered through Scriptapedia) to be evaluated in the context of the case study and potential contributors views on the process and results achieved.

Manuscript received April 16, 2014; revised July 25, 2014.

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Employing magnetic hexagons [4] is an example of a well-known (unformatted) script that was tested in the GMB workshops. An example of a formatted script for adding numerical values to a simulation model by participants placing a 'stake in the ground' is shown in Table I. From the table, it can be seen that a script can provide a useful means of achieving shared understanding between GMB participants by clearly laying out the context, purposes, nature of tasks, time and steps etc. of the GMB process.

TABLE I: EXAMPLE SCRIPTAPEDIA TEMPLATE OF A SCRIPT (SOURCE ROUWETTE, 2010)

Description	Participants are asked to predict the outcome of a modeling experiment. This script is an excellent way to generate lively and fruitful discussions and identify points for improvement of the model.
Context	This script can be used when a simulation model has been developed which is at least partially validated, so that there is a considerable degree of confidence in simulation results
Purpose(s)	• Making participants familiar with (assumptions in) a simulation model • Identifying points or further improvement of a simulation model
Nature of group task	• **Divergent**: participants' arguments for expecting a certain model output are made explicit • **Convergent**: the model is used to test participants' expectations on outcomes and in this way is expected to bring these closer together • **Evaluative**: testing participants' ideas involves identifies those ideas that are inconsistent with other knowledge on the system modeled
Time	Preparation time: for a more complex model it will take longer to set up the model simulation Time required to complete steps in script: eliciting comments, running the model and discussion afterwards will probably take around 20 – 30 minutes per simulation Follow up time: if changes in the model are required this may involve another session; if no changes in the model are required participants' confidence in the model is probably increased and no additional follow up (for this particular script) is needed
Materials needed to complete script	• Computer, projector and projection screen • Simulation model • Behavior over time graph to show baserun • Paper if expectations on simulation output are going to be written down, preferable behavior over time graphs showing baserun of variable(s) of interest
Inputs from other scripts	• Behavior over time graph to show baserun • Simulation model
Outputs from this script	• (Possibly) list of further improvements in model structure
Modeling team roles required and expertise needed	• Facilitator to guide group process • Modeler/ SD expert to interpret and explain model behavior in terms of structure
Who is in the room?	• All participants, facilitator and modeler
Steps	1. Briefly summarize main assumptions and parts of structure of the model (I assume that the audience has seen or worked with the model before, or at least is familiar with the model to some extent). 2. Present baserun of the variable(s) of interest. 3. Explain the variable to be changed and how it will be changed. At the start of the exercise, in each simulation only one variable will be changed. Later combinations of changes in variables may be used. 4. Invite participants to write down individually how the variables of interest will change. Ideally participants will draw the expected behavior in time graphs of baserun of variable(s) of interest. 5. Identify differences between predictions and ask participants to discuss differences (before the model is run). 6. Simulate the model with the changes (explained in step 2). Present results in behavior over time graphs. Explain differences to baserun in terms of model structure. 7. Compare model output to predictions and ask participants to discuss differences. Does the output correspond to expectations and are the structural explanations similar? Then the conclusion is that the model has passed another test and probably 1. participants have gained insight into their problem (they changed some of their ideas on system structure) and 2. confidence in the model is increased. Does the model behave differently and participants do not think the structural explanation corresponds to their experiences of the issue to be captured in the model? Then a list of model improvements can be drawn up. Very probably a mix of both will be the case.
Evaluation criteria	• Participants' insight into the issue increases • Participants' confidence in the model increases
Author(s)	Barry Richmond [21]
History & Basis for Script	I saw this script first in two papers by Barry Richmond (see below). I am assuming similar processes have been used in modeling classes and projects for a long time, although I know of no other publications.
Revisions	Translated into 'script language' Etiënne Rouwette September 2010
References	Richmond, B. (1987). *The strategic forum: from vision to operating policies and back again.* Paper High Performance Systems. Richmond, B. (1997). The strategic forum aligning objectives, strategy and process. *System Dynamics Review* 13(2): 131 – 148.

Groups can be empowered by selecting appropriate scripts used to address issues involving dynamic complexity in socio-technical systems when building models together. First adopted for system dynamics by Vennix in his influential book [5], Group Model Building (GMB) is the common term used to describe group-based system dynamic model construction. GMB is used typically either for quantified simulations of the problem (and trialing resultant intervention opportunities) or qualified concept model. An example of the latter is a causal loop diagram that indicates relative influences between connected factors in a system involving feedback and is commonly used to structure complex dynamic problems.

Models constructed through GMB can be employed to help mediate disputes over complex issues between participants who might otherwise disagree [6]. GMB facilitation methods encourage problem owners or stakeholders to take part in model development and

subsequently adopt future outcomes predicted by a simulation model through clear and transparent or 'white-box' construction processes [7]. GMB also seeks to overcome the heuristics inherent to "traditional" decision making through integrating and structuring available information [8]. The process of modeling can support capture of qualitative plus judgmental data within quantified model formulations [9], principally by employing descriptions of elicitation processes for sub-models known as scripts. A compendium of deployed and developing scripts has been published; the most recent version, Scriptapedia 3.05, indicates the primary nature of the group task as either divergence or convergence of ideas. Typically convergent scripts help build models where divergent scripts expand ideas around the issue. For example eliciting hopes and fears of the group collects together divergent views on what success or failure might entail from the workshop for each participant before using a convergent script, debriefing those participating using a multi-method survey tool to ascertain views.

Facilitation is used to ensure that the outputs remain targeted at the issue being considered. Quantitative modelling combines diverse data sources to underpin simulations of the observed dynamic phenomena. Most scripts are designed to achieve consensus but both assumption reversal and review-update concepts also feature amongst the published techniques [1]. The Scriptapedia compendium of scripts supporting different phases of GMB, is regularly updated to reflect growing body of practice. Such scripts can be applied to different cases of participatory model construction by first generating divergent insights on complex uncertainties followed by convergent views offering clarifications of the problematic behavior and potential intervention opportunities. It is noted that scripts can compress traditional multi-phase model build into only three workshops.

Scriptapedia offers a collection of accessible GMB scripts that have been described and categorized using standard templates to aid facilitation and modelling by helping to establish positive stakeholder dynamics [10]. Pertaining to the issue under investigation, facilitating individual mental models into memorable GMB charts for subsequent incorporation and testing of a fully dimensioned system dynamics model can be achieved using GMB. Thoroughly understanding individual stakeholder motivations is necessary before combining them into shared perspectives on the issue at hand and represents an essential aspect of managing stakeholder dynamics. Again the concept of widening mental models through the application of a wide set of group cues (rather than a potentially limited and therefore incomplete set of individual signals) is explored through model building scripts that support complex participant feedbacks [10]. Authors recommend starting elicitation using shared natural language before moving participants on towards those specific goals met by creating formal models. Finally, selecting important variables to reflect in an unquantified, stock-flow diagram structure helps to ensure that quality insights can be harvested from system dynamics simulations concerning alternative policy option decisions across a range of factors.

In order to shrink workshops into time-bounded yet effective group engagements, developing modelling debates beyond the workshop confines is another important avenue of exploration. A further complimentary approach [11] to GMB modeling employs the concept of Delphi questionnaires, termed workbooks, not only support data elicitation but also identify likely participants from hard to reach groups. By meeting defined requirements through careful question selection, the task of developing accountable, policy decision improvement initiatives can be established remotely. However not all audiences are engaged and therefore committed to survey outcomes especially when remote and lacking accountability for proposed decisions. A process that involves the least investment of highly-prized participant time combined with the greatest clarity of communications to a receptive audience could offer better opportunities to engage. Here compressing workshop time through the use of scripts needs revisiting.

III. Methodology

The contribution that building shared models can make in translating messy issues into clearer problems through scripts, especially where participants have a rich stock of prior knowledge on the issues of concern, is recognized [12]. Such anecdotes and stories can be used to translate experience into examples that can be incorporated into a model. The importance of bringing the participants' different experiences and perspectives into the GMB process cannot be underestimated, particularly where participants may hold unique knowledge. Healthcare and education are two areas of public service within the UK where complexity abounds. Messy public sector topics addressed using GMB principles include a national shipping policy [13], emergency services management [14], criminal justice [15] and within this, even detailed policing themes [16] for example.

Selecting scripts for building models may therefore offer considerable efficiencies across public sector providers, especially when combined with greater effectiveness for resulting policy, when compared to a traditional meeting agenda (typically used to address shared multi-agency issues in the UK public sector). Starting with traditional system dynamics model construction processes, we now consider how theory and associated technology may help to reduce participant time commitments from the public-sector to a community health study employing GMB scripts.

The need to first expand ideas on the topic of modelling being considered is important for group work and the process of useful data collection for quantified model building. Divergence supports exploring the range, variety and constitution of issues that could be considered from different points of view offered by those participating in the session. As scripted sessions last anywhere between thirty minutes and three hours, summary information usually in the form of charts and graphics, enables the detail to be recorded in a shortened format for subsequent recall and review.

The information generated through a divergent script now has to be focused using system concepts and ideas through a further script that converges data towards a sub-model contribution that can be easily recalled and debriefed. The

chosen scripts have to compliment the overall workshop purpose with the right output products and therefore pairing complementary scripts is important for engaging contributions with a consistent approach. Ideally not lasting more than four hours from start to finish (including breaks and with refreshments on hand), helps to avoid discomfort and reversion to snap judgments (termed 'system one' [17] or impulsive decision making in management psychology). Greater confidence can be generated in script performance if the opportunity to pilot with a suitable group is available to the modeler/facilitator. This helps reduce risk associated with combining GMB roles [18]. It may also be useful to have alternative or back-up scripts if running with a group for the first time.

By contrast a longer five-phase process [7], one where time constraints do not apply, is traditionally used when not collaborating on model construction. The phases comprise conceptualizing model structure; eliciting feedback structure; equation writing and parameterization then; policy development. Each of the phases provides iterative detail on different parts of the model construction process. Modelling in this way is considered a more established route to system dynamics simulation but remains unsuited to working with groups that are unfamiliar with a modelling approach. It is noted that scripts have been used to help reduce all five phases into three workshops, given multiple supporting roles and enough time. However this now needs revisiting if a combined role is to develop a system dynamics model within a relevant group of participants.

A representative group was selected for the pilot topic from education, local government and health. An agenda was agreed with the two gatekeeper roles that enabled a wide range of potential scripts to be tested for their ability to condense the data elicitation process by ensuring maximum contributions from all attending. A debriefing script, based on electronic survey technology, then supported view collection and script verification at the end of the workshops.

IV. Case Study Results

GMB participants for the piloting workshops were selected for their wide ranging experience and expertise (half were current practitioners while the remainder were recently retired) in child education and health service provision. Represented in the group were primary and secondary teachers, head teachers, local council officers, teaching assistants, counsellors, psychologists and health managers.

The problem posed for piloting was the hypothesis that a bulge in student numbers now entering primary school reception classes in a city could manifest itself as a reduction in success rates for children obtaining their first choice of secondary school in five years time and beyond. The reduction in first choice placements could then increase delay and frustrate those families and children needing places upon transferring schools aged 11. Parent and child stress induction may result, causing demand for statutory appeals to increase pressure on council provided services. This will again introduce further delays and uncertainty providing a vicious feedback loop in a short space of time. 95% first choice placements currently enjoyed across the city would reduce and dissatisfaction with the system would mount, over-spilling into community health provision for those individuals who are unable to cope.

It was suggested that Child and Adolescent Mental Health Services and health commissioning may need to prepare for significant increases in demand for child services over a period of time where rates may suddenly rise. By working as a multi agency combine, it may be possible to model such emergent effects and decide ways of intervening that would reduce overall impact from larger cohorts of year 6 students planning their transfers into year 7.

Having decided to run a pilot in a realistic setting with experienced participants, key scripts forming the basis of individual workshops were chosen due to their adaptability. Table II provides further details of the workshops agenda.

TABLE II: The Agenda of Scripts for a Workshop

Function	Group 1	Group 2	Group 3
Key divergent script elicitation	Hexagon clustering	Graphs over Time	Nominal Group Technique
Aim of script	Discover multiple factors	Reveal systemic behaviors	Establish viable intervention

It was found that the piloting approach to script selection provided gatekeepers with a degree of familiarity while testing whether the individual scripts would provide the detail necessary to establish a quantified model.

Piloting with a representative audience was also the preferred approach for the solo researcher where views could be tested using a standard questionnaire that also supported a subsequent debriefing process. Through using electronic voting on questions, instant feedback on group-held views was provided to those participating, while also allowing a debriefing discussion to proceed at pace. Here specific scripts within the participative modelling process are tested to ensure that they produced adequate results and generate shared understanding that can be reflected in a common dictionary of acceptable terms. The piloting process enables differences and improvements to be assimilated before attempting to facilitate the scripts (now with the support of gatekeepers) on the selected problem for a live audience from those multi-agencies with a stake in the outcome. This helps reduce overall risk especially where one individual has to take responsibility for both modelling and facilitating. It is noted that recording has been previously established using live audio tapes and with contributor permission, this was the chosen solution for piloting GMB scripts with participants [20].

The initial results of the script selection demonstrated potential for achieving a rapid and constructive modeling intercession in practice. The value of a planned approach to GMB elicitation across separate workshops and multiple sessions will assist those involved in researching the community health issues i.e. around anxiety in children changing schools when aged eleven. Should further workshop time reductions become necessary, then the opportunity to quantify more model detail outside of workshops and potentially with Delphi questionnaires may

have to be re-evaluated [11] with attendant risks around accountability for responses and commitment to action outcomes.

Innovation is present in every workshop as long as the stories can be heard and facilitated. For example, during the Nominal Group Technique (a '365' process allows 3 policy topics to be recorded for 6 individuals each spending 5 minutes writing on their form before passing it to the left for comments by five others), a healthcare manager identified a scripted process improvement when top individual (unilateral) policy rules were commented in turn by others in the group. Having read other policy suggestions the improvement was then identified and integrated into a further policy option not previously considered that suggested a multi-agency combined approach for testing on a simulator i.e. an example of integrated (multi-lateral) policy development in action.

TABLE III: SCRIPT COMPRESSION FOR GMB IN COMPARISON TO OTHER APPROACHES

SD TRADITIONAL MODELING PHASES FOR SIMULATOR CONSTRUCTION (ADAPTED FROM ANDERSEN AND RICHARDSON , 1997)	SIMULATOR CONSTRUCTION BY SURVEY AND WORKSHOP (ADAPTED FROM VENNIX AND GUBBERS, 1994)	PILOTED SIMULATOR BUILD USING SCRIPT COMPRESSION IN THREE GMB SESSIONS (P2015)
1. Defining problem presenting reference modes eliciting reference modes audience, purpose and policy options	1.Defining problem interviews with organisational leaders	1.Defining problem interviews with agency leaders to identify drivers
2. Conceptualizing model structure sectors, a top down approach maintain sector overview while working within a sector stocks and flows by sector	2. Conceptualizing model structure 'stawman' modelling of stocks and flows by meeting with core modelling team reflecting participants	2 and 3. Conceptualizing model and eliciting feedback structures Graphs over Time script* for 'status quo' projections plus 'hoped-for' system responses based on developing emergent system structures
3. Eliciting feedback structure direct feedback elicitation capacity utilization (script) system archetype templates 'black box' means-ends (script)	3. Eliciting feedback structure survey questions based on simple flow chart	
4. Equation writing and parameterization data estimation (script) model refinement (script) 'parking lot' for unclear terms	4. Equation writing and parameterization detailed questionnaire based on detailed system diagrams	4. Equation writing and parameterization 'stake in the ground' estimating system response to varied inputs (unpublished script, Table I refers)
5. Policy development eliciting mental model-based policy stories create a matrix that links policy levers to key system flows 'complete the graph' policy (script) modeler/reflector feedback about policy implications formal policy evaluation using multi-attribute utility models scripts for 'ending with a bang'	5. Policy development meeting with engaged group to develop viable policy interventions	5. Policy development decisions informed by verifying results of inaction, unilateral and multilateral policy decision rules (modified Nominal Group Technique script)* presenting system behavior summaries explained using causal loop diagramming for indicating sustainable improvement policy decisions

Table III indicates how compression through selecting scripts can be achieved moving from the left hand column explaining the traditional [19] five phases [7] through Delphi questionnaire meeting-time reductions [11] on the way to the final right hand column decided for the doctoral research project (termed P2015) involving piloting key scripts* with a representative audience verifying script performance. It is noted that not all script material or durations were assessed during the pilot due to the lack of a developed system dynamics simulator for subsequent convergent scripts.

Based on results in Appendix A, script compression research looks promising to deliver an operable model based

on only three workshops with high quality engagement within window target periods lasting only three hours. Appendix B suggests that more has to be done in workshops operated by a single researcher to ensure that a balance can be struck between the rigor of model-based challenge to existing mental models and allowing all modeling factions to be heard through adequate facilitation. Here the disclosure of privately held perspectives is being told to the group whereas the question-based feedback from modeling may require enhancements through correctly identifying scripts that openly challenge previously held assumptions. Some of the key benefits that our workshop participants agreed on about using scripts in GMB include:

- Assisting putting ideas forward
- Assisting multiple views on issues
- Assisting deciding options for tackling issues
- Help change views on what ought to be done
- Helps think more creatively on issues
- Informs about influences surrounding issues
- Helps understand how contributor values relate to their views
- Helps challenge previous thoughts on issues
- Helps focus on really important factors
- Helps with the clarity of thought on positive and possible changes
- Helps meet the purpose more clearly
- Helps people work well in a team
- Helps provide sufficient information to engage in debate

V. Conclusions

Healthcare and education specialists are major participants in the modelling study of the dynamic phenomenon of school transition anxiety in children. They are not modelers but frequently observe the effects of emergent systems not always operating effectively. Their views are essential to successful modeling but specific gate-keeping roles have to be entrusted with script endorsement and accurate use of language to avoid wasting time for the majority of participants. The adopted process of piloting demonstrated the appropriateness of the scripts selected from those available for use with a community health related group of public servants. By using a filtering approach to selection, Scriptapedia formats enable reliable quantitative script choices prior to deciding relevant divergent-convergent pairs of scripts for data elicitation. The benefits of selecting suitable scripts for an audience include improved levels of engagement, more champions for a shared course of action and greater understanding of the consequences of particular policy interventions.

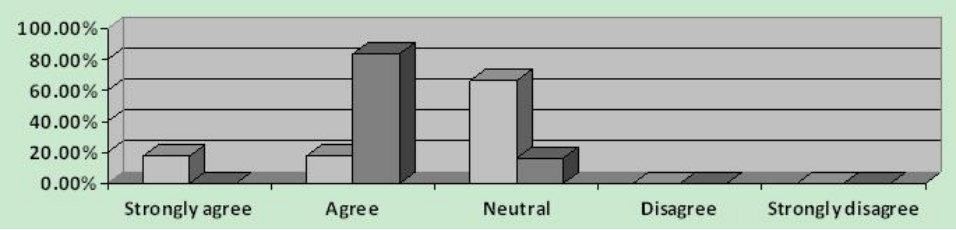
Quality communications are inferred from not only a common dictionary of terms used by the group but also through the clarity of elicitation processes supported by scripts. Certain qualitative scripts are also used to support process communication rather than data elicitation needs. For example, all workshops employ the qualitative debriefing script which does not extract data but instead clarifies workshop outcomes by reviewing sub-models collected throughout the workshop across individual scripted sessions. Survey results from the pilot day confirm that scripts were indeed suitable for generating relevant data and offered value to those participating in GMB from the target audience. New dictionary terms were also defined around the community healthcare problem during workshops.

Having reached our objectives of describing a pilot-based GMB approach, decomposing results from piloting selected scripts and re-formulating a compressed approach for audience-focused GMB workshops, the aim of establishing which GMB scripts to use has helped further reduced face to face participant time while maximizing the target group commitment (averting the need to resort to questionnaire responses from specialists where necessary assurances for subsequent action could be lacking).

APPENDIX A: Examples of Electronic Survey Results

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Total
Assists putting ideas forward	50%	50%				100%
Assists multiple views on issues	66.67%	33.33%				100%
Assists deciding options for tackling issues	50%	50%				100%
Helps change views on what ought to be done	16.67%	66.67%	16.67%			100%
Helps think more creatively on issues		83.33%	16.67%			100%
Informs about influences surrounding issues		66.67%	16.67%		16.67%	100%
Helps understand how contributor values to their views	16.67%	83.33%				100%
Helps challenge previous thoughts on issues	16.67%	16.67%	66.67%			100%
Helps focus on really important factors	16.67%	66.67%	16.67%			100%
Helps with the clarity of thought on positive and possible changes	16.67%	50%	33.33%			100%
Helps people work well in a team		100%				100%
Helps provide sufficient information to engage in debate	16.67%	83.33%				100%
Helps express own cultural viewpoint		83.33%	16.67%			100%

APPENDIX B: Comparison between Confidences in Model-Based Challenge Balanced against Trust in Facilitating All Views



ACKNOWLEDGMENT

The Authors would like to thank the staff of Plymouth Community Hospital, Woodlands School (Plymouth) and independent counselor, Lesley Banyard for their workshop contributions. The support of Dr. Etiänne Rouwette in providing example script formats has also been immensely helpful.

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