TIMES Version 2.1[1] Information Note: Enhancements and Updates

1 Current Activities

ETSAP continues to provide support for and enhancements to the TIMES model generator and report generator. This short Information Note describes these latest facilities.

2 Overview of New Capabilities and Updates

The main enhancements to TIMES embodied in Version 2.1 that impact the user directly include:

1. Several new options introduced for more flexible specification of User Constraints;
2. Activity-based transformation equations by using generalized PRC_ACTFLO;
3. Improved support for night storages, and support for auxiliary storage flows;
4. Automatic removal of redundant FLO_SHARE constraints; restrictions on the commodity groups used in FLO_SHARs relaxed;
5. Several small enhancements related to IRE processes (use of COM_TYPE as the PG, support for using FLO_BND, as well as IRE_FLOSUM and FLO_EMIS for the activity);
6. The calibration of the Climate module has been revised and enhanced.

These enhancements are discussed in more detail in Section 3. Other minor enhancements, corrections and bug fixes have also been made, as mentioned in Section 4.

Brief version history:

Version 1.5.0 – 2005-11-01

- Damage cost functions introduced;
- New migrating interpolation options and asymmetric extrapolation options introduced;
- Many new consistency checks and QA checks implemented.

Version 2.0.0 – 2005-12-01

- Stochastic TIMES introduced;
- TIMES-MACRO introduced;
- Multi-regional clustering introduced in the ETL module.

Version 2.1.0 – 2006-06-15

- Generation of user constraints revamped and several new UC_ATTR introduced;
- Improved support for night storage and inter-period storage, auxiliary flows supported;
- Many other minor improvements and bug fixes.

Those interested in the full history of improvements and changes to TIMES should turn to the version control information notes (in the file version.log).

[1] The TIMES Version number is composed of three digits, and perhaps a trailing letter (x,y,z,i). These are changed each time new code is posted on the ETSAP website (though they may also change during internal distribution) such that:

- x - changes rarely, only when a major change in how the model is run (e.g., if time-stepped mode is added);
- y - changes when any new equation is introduced to the model, resulting in a new TIMESx.y_Information;
- z - changes when a new variable or a new capability requiring additional input data is introduced to the model, or major bug fixes are remedied, and results in the new source code being posted on the ETSAP website; and
- i - changes each time the code is modified and distributed internally, prior to posting on the ETSAP website.

The version current number is reflected by the $TITLE line in the INITSYS.MOD initialization routine, and printed in the GAMS LST output file.

3 Main Enhancements

3.1 Enhancements in the specification of User Constraints

The user constraint facility in TIMES provides a very powerful tool for specifying a large variety of custom user constraints in a TIMES model. Such constraints can refer to practically any combination of individual variables. Moreover, the constraint definitions can be optionally refined by specifying additional attributes that are applied to specific components of the constraints. The attributes available in the current version are listed in Table 1. The attributes CAPACT, EFF, NET, PERIOD, and CUMSUM were introduced in version 2.1.0. The note "DYN only" in the table means that the attribute is valid for dynamic constraints only (the constraint is automatically defined as dynamic).

As indicated in Table 1, in the current version you can now easily specify, for example, that the FLO coefficients of the user constraint should apply to the sum of all annual flows in each period, by using the PERIOD attribute. In addition, as cumulative user constraints (summed over periods) are typically almost always meant to be applied also to the sum of the annual flows/activities in each period, the PERIOD attribute is now by default applied to the FLO, ACT, IRE, COMPRD and COMCON components of all cumulative constraints (this can be overridden by the explicit use of UC_TS_SUM). For example, in order to specify an upper bound on the cumulative production of the commodity 'URANIUM' by the processes 'UEXTR1' over the whole model horizon, both separately in the region 'EU' and globally, only the following specifications are needed:

```
UC_FLO('CUMURA','LHS',REG,'2000','UEXTR1','URANIUM','ANNUAL') = 1;
UC_RHSR('EU','CUMURA','UP') = 2.0e5;          ! Regional bound for EU
UC_RHS('CUMURA','UP') = 7.0e6;                ! Global bound
```

In earlier versions of TIMES, the period lengths had to be embedded in the coefficients, and, in addition, UC_T_SUM('REG','CUMURA',T), entries had to be defined for all model periods T, UC_R_SUM(REG,'CUMURA') entries for all regions REG, UC_R_EACH('EU','CUMURA') entry for region EU, and UC_TS_SUM(REG,'CUMURA','ANNUAL') entries were also required for all regions REG. The new version thus makes the specifications easier, by assigning defaults according to the type of the UC constraints and the RHS constants as specified by the user.

Table 1. User constraint attributes available in TIMES.

Attribute	Description	Applicable UC components
COST	Multiple by primary cost attribute (sum with other cost attributes)	NCAP,ACT, FLO,COMPRD, COMCON
TAX	Multiple by tax attribute (sum with other cost attributes)	NCAP,FLO
SUB	Multiple by subsidy attribute (sum with other cost attributes)	NCAP,FLO
DELIV	Multiple by delivery cost attribute (sum with other cost attributes)	FLO
CAPACT	Multiply by PRC_CAPACT	CAP
LO, UP, FX	Multiply by bound (not of much use, but included in original TIMES)	CAP
EFF	Multiply by COM_IE (UC_COMPRD), divide by COM_IE (UC_COMCON)	COMPRD, COMCON
NET	Apply to *net* production (UC_COMPRD) or consumption UC_COMCON)	COMPRD, COMCON
GROWTH	Interpret coefficients as annual change coefficients (DYN only)	All
PERIOD	Multiply by period length (all but NCAP) or COEF_RPTI (NCAP)	All but CAP
CUMSUM	Sum over all periods up to current or previous period (DYN only)	All

Additionally, the components UC_COMPRD and UC_COMCON have been refined in the current version. UC_COMPRD now applies by default to the gross production of the commodity (i.e. the impact of COM_IE is eliminated). By using the EFF attribute, one can refer to the net production after COM_IE, and by using the NET attribute to the net production with consumption subtracted. The UC_COMCON component now applies by default to the total consumption of the commodity. By using the EFF attribute, one can refer to the corresponding gross amount before COM_IE, and by using the NET attribute one can refer to the net consumption after production has been subtracted (equal to the net production after COM_IE, but with opposite sign).

Remark 1: The TIMES shell VEDA-FE provides a dedicated attribute ('CUM') for cumulative process flow constraints, and VEDA-FE embeds the period lengths in these constraints. Although such embedding of period lengths into the coefficients is in general not recommended, the model generator maintains full backwards compatibility with VEDA-FE in this respect (these cumulative constraints work as before). Note that without full re-import VEDA-FE might fail to update the coefficients when periods are changed.

Remark 2: The TIMES shell VEDA-FE currently supports only a few special types of TIMES user constraints (the CUM constraints mentioned above, basic market share constraints for technology groups, and bounds on the total sum of input/output flows, total capacities, or new capacities of groups of technologies). In addition, neither the UC_ATTR attributes nor the UC_R_SUM, UC_R_EACH, UC_T_SUM, UC_T_EACH, UC_T_SUCC or UC_TS_SUM/EACH qualifiers are supported. Consequently, only a small part of the various types of TIMES UC constraints are currently available under VEDA-FE.

3.2 Activity-based transformation equations by using PRC_ACTFLO

Simple activity-based transformation equations represent one common type of process equations frequently needed in TIMES models. In the TIMES user shell VEDA-FE, the Input and Output attributes can be conveniently used for specifying fixed relations between the process activity and individual input or output flows that are not part of the primary group (PG). In standard TIMES, however, there has been no means to specify a relation directly between the activity and a flow, because e.g. FLO_FUNC and FLO_SUM operate between flows only.

The PRC_ACTFLO parameter is used in TIMES for specifying the conversion factors from the activity to the commodity flows in the primary commodity group. In the TIMES version 2.1, the parameter has been generalized in such a way that it can also be used to specify the conversion between the activity and any individual non-PG commodity. Consequently, when used for non-PG commodities, PRC_ACTFLO works exactly in the same way as the Input/Output attributes in VEDA_FE. This natural generalization can be summarized as follows:

- PRC_ACTFLO specified for the primary group (PG) or individual commodity in the primary group gives the conversion factor between the activity and the commodity flows in the primary commodity group (as in previous versions).
- PRC_ACTFLO specified for an individual commodity not in the primary group gives the conversion factor between the activity and the commodity flow of the non-PG commodity. The result is a fixed transformation equation between the activity and the flow.

The generalized PRC_ACTFLO parameter can be used for all types of processes, including auxiliary flows of IRE and STG processes. The limitation of the parameter is that you cannot differentiate the parameter value according to timeslice.

3.3 Enhancements related to storage processes

The TIMES model generator provides tools for specifying the following types of storage processes:

- Standard timeslice storage (STG without additional storage type qualifier)
- Day/night storage (STG+NST)
- Inter-period storage (STG+STK)

The enhancements in the current TIMES version include the following:

- Day/night storage processes can operate at the ANNUAL level and can produce ANNUAL level commodities. This is useful for end-use technologies that directly produce ANNUAL level demand commodities, for which a load curve has been specified.
- The handling of the initial stock of inter-period storage has been improved, and it works now well for both vintaged and non-vintaged storage facilities.
- Storage processes can now produce and consume auxiliary commodities (emissions, electricity, fuels, waste etc.). The flows of such auxiliary commodities can be defined to be proportional either to the activity, the main input flows, or the main output flows of the storage.

3.3.1 Day/night storage

Day/Night storage processes that produce ANNUAL level demand commodities can now be modeled as either genuine storage processes or normal processes with a night storage capability. In both cases it is sufficient that the process type is defined to be 'NST'. If the process is defined to operate at the DAYNITE level (or any other level than ANNUAL), the process will be a genuine storage process, but if it is defined to operate at the ANNUAL level, it will be a normal process. In both types of NST storage, the demand commodity is produced according to the load curve, but the charging can be optimized so that it occurs at night timeslices only. However, when the NST process is a normal process, it can be described in all other respects just as any other end-use technologies. For example, electric heating systems with accumulators can be described basically in the same way as direct electric heating systems, but with the additional night storage capability.

3.3.2 Inter-period storage

The allocation of the initial stock of an inter-period storage process is now left to be optimized by the model between the vintages available at the beginning of the model horizon. Earlier the whole initial stock was allocated to the newest available vintage, which could lead to unnecessary investments. The initial stock can be specified by using the STG_CHRG parameter, which is interpolated so that it always includes the year at the beginning of the model horizon (B(1)-1). The value of STG_CHRG in the year B(1)-1 is used as the initial stock for inter-period storage.

3.3.3 Auxiliary storage flows

Until TIMES version 2.1.0, storage processes could not have any other commodities that the main commodity that is stored. For day/night storage, however, the input and output commodities could additionally be different from each other. In the new version, this restriction has been relaxed.

Storage processes can now have any amount of auxiliary input or output commodities, as long as they are distinct from the main storage commodity. The flows of the auxiliary commodities can only be defined to be fixedly proportional either to the activity, the main input flows or the main output flows. The main flows of timeslice storage are identified by the set PRC_STGTSS(r,p,c), and those for inter-period storage are identified by the set PRC_STGIPS(r,p,c). In day/night storages the main flows consist of all commodities in the primary and shadow groups of the process (see documentation).

The relation between the auxiliary flows and the activity or main flows should be defined by using the PRC_ACTFLO and the FLO_FUNC parameters. If both the primary group and the main flows of the process consist of the commodity 'STORED', and the auxiliary commodity is 'AUX', the auxiliary flow can be defined in the three following ways, corresponding to the cases where the auxiliary flow is proportional to the activity, the input flow, or the output flow, respectively:

```
PRC_ACTFLO(r, t, p, 'AUX')              ! AUX proportional to activity
FLO_FUNC(r, t, p, 'STORED', 'AUX', s)   ! AUX proportional to input flow
FLO_FUNC(r, t, p, 'AUX', 'STORED', s)   ! AUX inversely proportional to output flow
```

Remark: In the TIMES user shell VEDA-FE, the FLO_EMIS parameter with the ANNUAL timeslice can also be alternatively used instead of the first relation type (FLO_EMIS(r, t, p, 'ACT', 'AUX', 'ANNUAL')). FLO_FUNC is currently not supported by VEDA-FE, but the second relation type can be in most cases defined under VEDA-FE by using the VDA_FLOP parameter (assuming that the input flow is in the PG). The third relation type seems to be currently unsupported in VEDA-FE, due to the lack of FLO_FUNC support.

These auxiliary storage flow relations have been implemented by adding a new TIMES equation ***EQ_STGAUX(r, v, t, p, c, s)***. As the auxiliary storage flows are represented by standard flow variables, any flow-related cost attributes and UC constraints can be additionally defined on these auxiliary flows. However, no transformation equations can be defined between any auxiliary storage flows. Therefore, if, for example, some auxiliary flows should also produce emissions, also these emissions should be defined on the basis of the activity or main flows, and not by defining a relation between the auxiliary flow and the emission flow. Consequently, it is required that all auxiliary commodity flows related to storage processes, whether energy, material or emissions, are described by using the three types of relations shown above.

One concrete example where these enhancements to the storage processes can be very useful is the modeling of waste management, and, in particular, the modeling of landfilling of different types of waste. Using inter-period storage processes for this purpose makes it possible to conveniently incorporate e.g. the following features in the waste management model:

- Modeling of methane emissions from landfilling in a dynamic way by using first-order decay functions for the gradual waste decomposition (optionally with different rates of decay for different waste qualities);
- Modeling of other waste management and emission reduction options both before and after landfilling;
- Incorporating gate fees to landfill sites (by defining costs on an input-based auxiliary storage flow).

The first-order decay functions can be conveniently described by using the STG_LOSS atribute, and the emissions by an auxiliary activity-based storage flow.

3.4 Enhancements related to FLO_SHAR

The TIMES FLO_SHAR parameter can be used to define constraints on the shares of individual commodity flows in the total flows among a group of commodities related to the same process. This parameter is particularly important with respect to the calibration of TIMES models. Unfortunately, FLO_SHAR constraint groups are easily overspecified. A common example is the case where all commodity flows in the group should have a fixed share. In this case one of the flows should be left without a FLO_SHAR constraint, because otherwise that would be either redundant or inconsistent.

The new version lifts the burden of checking for overspecifications from the user. The model generator now identifies many types of redundancies and inconsistencies resulting from over-specification of FLO_SHAR parameters. Redundant parameters are normally removed without warning. TIMES also makes an attempt to fix inconsistent FLO_SHAR constraint groups by removing some of the constraints, but in this case a warning is also written into the QA log. Such corrections are typically related to only slightly inconsistent constraints, and these should have no impact on the intended model behaviour. Nevertheless, the user should check the causes for these warnings.

In addition to the consistency checks, the FLO_SHAR equations have also been somewhat generalized in the new version. The reference group of the parameter is no longer required to be in the set PRC_CG. In addition, if desired, it is now also possible to specify a relation between a reference group and a commodity not included in that group. This latter relaxation was introduced primarily due to the remaining limitations of the VEDA-FE shell (the powerful FLO_FUNC or FLO_SUM attributes of TIMES are not yet supported), and should be exploited with care.

3.5 Enhancements related to IRE processes

The following enhancements have been made with respect to inter-regional trade (IRE) processes:

- Commodity type can be used as the primary group of IRE processes. As a result, all commodities imported or exported through the process will be included in the primary group.
- The FLO_BND parameter can now be used for the import/export flows of IRE processes. The bound will apply to the sum of both imports and exports of the given commodity.
- When using the VDA extension, FLO_EMIS can be used on the activity of IRE processes, by specifying 'ACT' as the source group. Similarly, IRE_FLOSUM can also be specified on the activity, in the same way.
- Top entries are automatically created on the basis of IRE_FLOSUM and FLO_EMIS.

3.6 Revised calibration of the Climate Module

The calibration of the Climate Module has been refined and enhanced in the following aspects:

- The historical data on concentrations and temperatures are now assumed to refer to end-of-year values, in conformity with the convention used for the climate variables.
- The mass balance equations can be calibrated for the first period by using three alternative calibration years B(1)–1, m(1)–1, and m(1). Whenever D(1)=1, the first two alternatives are equal. The default calibrating year is m(1)–1. The alternative calibration years can be activated by using one of the following two settings in the run-file:

```
$SET CM_CALIB B        ! Calibrate at the end of B(1)–1
$SET CM_CALIB M        ! Calibrate at the end of m(1)
```

4 Code Fixes and Minor Adjustments

Various minor adjustments and corrections have been made to the code since the TIMES master documentation was finished in April 2005. Small impacts on backwards compatibility can arise only in a few cases (marked with ○). The following list summarizes the most important fixes and other minor improvements since version 1.4.0 (June 2005):

Version 1.5.0 – 2005-11-01

- Bug fixed related to calculation of flow costs of IRE processes.
- Bug fixed related to costs from capacity-related flows.
- Bug fixed in UC_COMCON.mod, which referred to non-existent variable;
- Bug fixed in calculation of costs due to IRE_PRICE.
- Bug fixed in related to shaping of emissions when REDUCE=YES.
- Bug fixed related to reporting of auxiliary flows from IRE processes.
- ○ EQ_INSHR/OUTSHR changed to be generated at the level of the flow variable due to problems in the original formulation when the process operates at ANNUAL level.
- Several FLO_SHAR consistency and redundancy checks added.
- Various performance improvements, especially in interpolation and fixed cost accounting.

Version 2.0.0 – 2005-12-01

- Damage functions now work also for global CO_2 concentration, if CO2-GTC is used as the emission commodity.
- All ETL equations changed to be triggered by SEG(r,p), which has to be provided anyway. This change facilitates multi-regional clustering, for which a new input parameter (TL_MRCLUST) and a new equation EQ_MRCLU are introduced.
- Memory usage of the model generator notably reduced by improved matrix reduction.

Version 2.1.0 – 2006-06-15

- The faulty version of EQDECLR.tm for TIMES-MACRO in v. 2.0.0 was fixed;
- Bug fixed in the reporting of storage flows, which could inherit activity values;
- Bug fixed in the stochastic reporting of Climate Module results with zero emissions;
- Bug fixed in the reporting of processes with no activity variable;
- Bug fixed in the objective function component related to COM_CSTPRD.
- Bug fixed in the flagging of RHS_COMxxx in the case of COM costs or UC_COMxxx;
- Bug fixed in the ETL extension related to cumulative capacities of Case 1b investments;
- Added support for using 'ACT' in PRC_ACTFLO;
- Added levelising of UC_COMPRD and UC_COMCON parameters;
- Added automatic generation of NCAP_AFAC for pass-out CHP (VDA extension);
- Changed preprocessing of FLO_EMIS so that it can override VDA_EMCB (VDA);
- Changed the name of set EXP to avoid future conflicts with the EXP function;
- Small improvements have been made into the QA checks.

All the features reported on in this information note, and all previous versions of TIMES, will be fully supported in forthcoming releases of VEDA-FE/TIMES!

For more information on the ETSAP model generators, TIMES and MARKAL, contact the ETSAP Primary Systems Coordinator (Gary Goldstein, DecisionWare, Inc, ggoldstein@irgltd.com).