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Chapter 1 – Background

Machine costing and productivity parameters

Stellenbosch University and FESA have developed three highly researched and implementable mechanisms with which to evaluate, control, and manage individual machines or machine systems (both for biomass harvesting or mechanized silvicultural systems) and their operating systems, production and productivity. Both mechanisms have been developed to match international benchmarks for both time-studies and machines and systems costing and productivity optimisation.

These are:

- The South African harvesting and transport systems costing model
- Standards for time–studies for the South African forest industry (www.forestproductivity.co.za)
- Time-study App (nearly complete)

The time-study standard is the latest development and is also the first of its kind available both in South Africa and internationally. The costing model is also unique globally. The costing model and

time-study standard work together to a common end which is machine and systems cost and productivity optimisation as the time-study standard provides information and protocols for input into the costing model.

Time-study standard

In more detail, the South African Standard for Time-studies provides a common and standard time-study methodology for the South African Forest Industry; a protocol that does not currently exist. Its implementation serves the purpose of aligning the South African Forest Industry with international forest operations development and assist with the "modernisation" of the Industry's forest operations. The concept of modernisation essentially includes updating forest operations in terms of both mechanisation and other modern systems improvements with the goal of improving wood/fibre yield, wood/fibre quality and reducing production costs to remain locally and internationally competitive.

The Standard has been compiled by those with specific expertise in work- and time-studies, particularly the statistical analysis component and machine costing. The Standard, with the inclusion of an internationally standardised Machine Costing Model, was developed based on accepted and validated international Time-study standards, protocols and literature. This Protocol is envisaged to be a state of the art model to benefit the South African Forest wood supply chain.

The Standard will be web-based and will guide the user step-by-step through the set up and execution of time studies and their application in Operations Research analysis. The standard deals with the setting of time-study objectives to ensure that time and resources are used efficiently and help to develop the desired results. Three types of studies, observational, experimental and modelling, are introduced. Different techniques are provided to control bias (i.e., systematic error) including randomisation and blocking.

The Standard contains sections on experimental study design, data collecting methodologies including sample size calculations; time study models; statistical analysis and methods to best analyse the data collected; and ways to use and proceed with the results achieved through linkage with a machine costing model. In the web site version the user will also be able to calculate machine availability, utilisation and systems efficiency ratios that are useful in determining systems efficiency. Background data forms, a terrain classification, templates to create data collection forms for the user's study and a brief discussion on available time study software and equipment are also included.

Included in the Standard there is a Time-concepts model developed by the International Union of Forest Research Organisations (IUFRO), useful for the precise division of common time elements included in all work and production systems.

The Standard also describes in detail the six different scopes of time studies, ranging from wide to narrow. These studies are shift-level, plot level, cycle level, time and production count, working sampling and the element level. Each study has different strengths and weaknesses and requires a specific technique which is discussed. A statistical analysis manual is also in the drafting stages and will aid the user through conducting their analysis and interpreting the results.

Costing model

The costing model provides the South African Industry with a common calculation tool with which to determine costs of any harvesting and transport or silvicultural system in an unbiased and scientific way. The protocol contained in the model is common to detailed research of international convention and as such is unique. The South African Harvesting & Transport System Costing Model was developed for the South African Forest Industry and includes both large and emerging contractors. The model's function is the costing of harvesting and transport equipment and current and potential harvesting systems. The model requires specific cost-related inputs from which it generates relevant costing information. The programme essentially contains 20 machine-specific individual equipment costing models and a system costing protocol. Individual equipment models can be used for costing of individual machines, which in turn can be used in the system costing model. The system model accommodates manual, semi-mechanised and mechanised systems and is not aimed only at one specific type of harvesting system or system technology.

The system model balances the number of units of equipment required, a first for a South African costing model. Apart from equipment, the model includes personnel (operators, labour and additional personnel), overheads, risk, incentives, profit and a sensitivity analysis option. The ideal number of units for each activity, costs, production and productivity of the system are all calculated by the programme.

Advantages of the model include:

- Equipment balancing optimisation.
- Identification of unnecessary incurred costs.
- Help in the management of necessary costs.
- Reduction of the likelihood of under- or over-quoting for contractors.
- Prevention from costs overlooking.
- Prediction of the productivity of the system over time.
- Cost comparison of proposed systems before one is selected.

Research question

One of the main indications that are addressed by the time-study standard is the all-important factor of estimated productivity, as all systems need to produce work at its full potential. However there are a number of other parameters that require input and which work in tandem with productivity to produce an even more meaningful solution to the question of optimising productivity and cost. Without an accurate estimation of these input values (experienced machine owners and operators may well know what can be expected) the everyday contractor and most certainly the emerging contractors cannot manage and control his work.

The four most important factors requiring input are:

1. Machine utilisation (a parameter directly related to machine's expected economic life)
2. Fuel consumption (the actual fuel consumption of a machine under different operating conditions)
3. Oil and lubricant consumption (the actual oil and lubricant consumption of a machine under different operating conditions)
4. Maintenance and repair costs (the cost to maintain a machine in working order so that it can effectively produce work it is designed for)

Apart from point one above, which can only be solved through long term shift level studies where all facets of the operation are recorded (with the all-important time component), the others require in-depth research into long term records of existing and perhaps more importantly from machines and systems starting from scratch. Very little international literature can be found which addresses points 2 to 4 (although it may be specific to a country). Another challenge is that if some data are available it is very difficult to translate because of the different methodology used to collect them.

Other relevant information to increase the meaningfulness of the model would be:

- Machines running gear (what life-time for tyre, tracks and tyre chains can be expected under differing operating conditions)
- Operators' working conditions (training level, physical conditions, environmental conditions)

Chapter 2 – CNR short term mobility programme

The Italian National Research Council (CNR) Short Term Mobility (STM) Programme enables Italian scholars to carry out research activities in cooperation with foreign Universities and Research Institutions of clear international standing.

CNR finances short - term stays of 21 days of Italian researchers and the Programme has been implemented with success since 1995, in the framework of the initiatives for the development of international scientific cooperation.

Dr Carla Nati, permanent researcher at IVALSA (Timber and Tree Institute) applied for a STM with a research programme titled: "Development of a common standard to match international benchmarks for costing and productivity optimization into the harvesting timber industry".

Main scope or the programme was:

- Providing a refinement, a calibration of the current costing model, in order to make it a better to tool in contractors' and users' hands, in a South African context.
- To widen the use of the costing model to a European context, by including more case studies and so more inputs, concerning for example the kind of forestry machines, tree species, and terrain and operating conditions.

Chapter 3 – Activities

As previously stated, the programme research will involve the development and testing of a methodology for measuring, determining and evaluating the array of inputs required for a meaningful timber harvesting machine costing. The following are the targeted inputs values:

1. Machine utilisation (related to delays – non-work time, work related delays, productive work time, supportive work time, service time and ancillary work time)
2. Fuel consumption
3. Oil and lubricant consumption
4. Maintenance and repair costs

Main activities to carry out during the STM:

- A review of the available literature: articles will be searched entering key words through the two most effective scientific article browsers, Scopus and Google Scholar. Two lists will be available at the end of this activity: a *comprehensive* list in a Word format, which will contain all the articles found, downloaded, and skimmed according to the topics of interest; a *specific* list as Excel spreadsheet format, which will contain the figures of interest. This second list will include: reference's citation, operating context, and relevant values. The spreadsheet will contain four electronic sheets, one for each topic, and namely: machine utilisation, fuel consumption, maintenance & repair, oil & lubricants consumption.
- Interview to representative contractors in the forestry sector in order to exchange ideas on the inputs that are believed to impact mostly on the actual costs of forestry operations. Contractors will be asked to join the research by sharing information concerning productivity, assortments, species harvested, fuel & oil consumption, and repair & maintenance costs.
- Draft of a dedicated questionnaire. According to the data collected from contractors, a simple spreadsheet containing the most relevant information will be prepared and submitted to other contractors to ease the fulfil and the gathering of relevant data.

Chapter 4 – Output achieved

- Literature review: 30 articles have been read and reported in the previously mentioned lists. Overall, were found 10 articles dealing with "Machine utilization", 9 reported information on "Fuel consumption", 12 on "Maintenance&Repair" and only 2 on "Oil&Lubricants consumption".
- On 14th and 15th of May, 2015 Simon Ackerman, Research Scientist at the Forest Operations Research Institute for Commercial Forestry Research Scottsville, and Carla Nati from CNR-Ivalsa, visited Mr. Danie Scheepers manager of Enviromech enterprise, in the county of Kareedouw, 560 km East-North from Stellenbosch, near Storms River Mouth Rest Camp. The contractor explained in detailed his activity and that he was interested in joining the research to have

leverage during negotiations with the dealers and clients. He took the visitors to a field operation nearby, where a harvester, a loader and a forwarder were working in a *P. radiata* stand.

- After that he was shown the current version of the Costing Model and a simulation with contractor's figures was carried out.

Fig 1 – The forwarder John Deere 1710D

Mr. Danie Scheepers agreed to send data for the last 2 years, collected on a monthly basis, about compartment, hours worked, volumes invoiced for that month, cost information - with the individual items and costs for those items for the month, productivity per day/operator, and fuel & oil consumption data per each machine.

Fig. 2 – The harvester John Deere 753JH

- After the visit, an official and more explicative E-mail has been sent to Mr. Danie Scheepers on 18th of May, 2015 explaining in more detail the kind and the framework of data to be collected.
- The worksheet has been simplified since its first draft, in order to save time and make the contractors more incline for collaborating.

Chapter 5 – Future output

- The University of Stellenbosch will share the Costing Model with CNR Ivalsa with the aim to get the stakeholders aware of its potential for costing forecast.
- Refinement of the questionnaire. The questionnaire will be further modified and tailored on the Italian context, but it will substantially contain the same fields to be filled in.
- CNR-Ivalsa will contact Italian public managers and private contractors active in the timber procurement to involve them into the project. A preliminary list of 17 subjects has been drafted.
- An analysis of the data collected will be carried out to determine the variables affecting the system, find the equations to be set into the costing model, and achieve a more accurate result for productivity and costs in forestry operations.
- After the data analysis, an international scientific paper will be wrote by CNR-Ivalsa in collaboration with the Department of Forest and Wood Science (Stellenbosch University, South Africa) and the Institute for Commercial Forestry Research (Scottsville, South Africa) by using the literature review carried out during the STM, integrated with the latest articles that might be released on the topic in the meantime.