# DECISION ANALYTICS—LESS EXPECTED MOTIVATORS FOR HEPA PROGRAMS

CHRISTER CARLSSON
Institute for Advanced Management Systems Research, Abo Akademi University, Abo, Finland
christer.carlsson@abo.fi

There is a need to raise the physical activity levels in the population as this will give significant savings in healthcare costs, both long- and short term. This has motivated numerous projects and campaigns during the last 15-20 years, which mostly have not produced any long-term, and not any significantly positive results. We need "some better ways", which build on the design of programs for young elderly (our target group) that get adapted to and adopted for sustained use. Decision analytics could be a possible approach to find the wanted "better ways". The DigitalWells program is a first implementation of decision analytics with (at least) partial answers to the complaint - "you cannot be sure that time spent will actually give sufficient health effects" – a key reasons why exercise programs are discontinued. DigitalWells is a digital ecosystem, an effective and useful context for advanced digital analytics, which offers better forms for user guidance and support.

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## 1 Introduction

In a recent study [18] the authors state as an established fact that low physical activity and high sedentary behaviour unquestionably have an impact on public health and will also increase direct and indirect costs. One way to summarize the result is the estimate that the total costs of low physical activity in Finland [18] in 2017 was 3.2 B€ (direct costs 683 M€, indirect costs 2.5 B€) and costs of high sedentary behaviour roughly 1.5 B€. We will not work out the models that generated these estimates but accept the contention that low physical activity and high sedentary behaviour levels carry substantial societal costs; prior studies referred to in [18] state that physical inactivity cause about 0.3% - 4.6% of a nation's healthcare costs. Thus, one conclusion that can be made is that raising the physical activity levels in the population will give significant savings in healthcare costs, both long-term and in the short term (cf. [13]). This insight has motivated projects and campaigns that have targeted various groups and segments of the population at various points during the last 15-20 years (if we restrict the discussion to more modern efforts), but it appears that these efforts have not produced any long-term, and not any sustainable, significant, and positive results. Projects and campaigns come and go (cf. [13], [18]) and it appears that collection of facts or systematic databases, that can be reused as references and starting points for renewed studies have not been created and maintained.

Our conceptual framework builds on the theory, history and systematic knowledge built in the constructs of information systems, which in turn is part of the ICT framework, and which will offer some insight and some means to work out the problems with non-sustainable efforts to raise the physical activity levels in the population.

The first decision we need to make is that we should not try to find or build generic solutions that could apply to all groups and segments of the population. We have a better possibility to find viable and useful solutions by working with definable problems for specific (but sufficiently large) groups (cf. [18]). We decided on working with the young elderly, the age group 60-75 years, which public policy more or less ignores in planning and programs for the ageing population – common wisdom finds that they are too healthy, too active, and with too good social networks to need any intervention and support from public resources; and they are too many (about 1.3 million citizens in Finland, 23% of the population) – the last point is a sarcastic interpretation of prevailing political opinions. Nevertheless, it makes good sense to build preventive programs to counter the effects of ageing early enough – with a focus on young elderly – to get timely, sustainable, and long-term results for ageing citizens (cf. [18]).

A second decision is to focus on what we mean by "raising the physical activity levels" and bearing in mind that we want to carry this out for the young elderly. HEPA is an acronym for health enhancing physical activity, which translates to physical activity (PA) of enough intensity and duration to give short- and long-term health effects. In health recommendations regular PA at moderate intensity for at least 150 minutes per week is expected to have positive health effects (cf. [14]). The European HEPA network claims that thirty minutes a day of moderate-intensity activity is enough to benefit health. This type of recommendations offers some guidelines but appear to be insufficient as motivators to raise PA levels – in field studies (cf. [10-12], [15-16]) we have seen comments like – "you cannot be sure that the time spent will actually give sufficient health effects". The HEPA recommendations apply to healthy adults with individual differences in the effects of PA programs. There are variations when we focus on young elderly, in terms of female/male, age groups, BMI, socio-economic background, history of physical demands from work history and HEPA capacity (decided by PA history and physical shape). Work with young elderly (cf. [10-12], [15-16]) showed that PA programs offered in projects and campaigns over several years, (i) were not intensive enough, (ii) were not running for enough time (cf. [18]), and (iii) were not regular enough to be adopted and become sustainable habits for young elderly. Thus, we need to work out some better ways to design, introduce and sustain HEPA programs for young elderly.

These two decisions form the context and the limitations of the paper, we do not aim for any generalizations – any general principles or theory. The methodology used in the DigitalWells program is a combination of building new, innovative artefacts combined with technical testing and verification of software solutions and functions, and empirical testing of usability and relevance with samples of young elderly users (cf. [4] for similar studies).

The "some better ways" points to systematic thinking and rational decision-making, the key principles of which have been close to us for more than 50 years (cf. [25]). Following the axioms of decision analysis, the best decision to choose (e.g. the best PA program) is the one whose consequences have the maximum expected utility or offer the maximum probability of achieving a wanted aspiration level (e.g. getting better sustainable health). Since the early, rather theory-oriented days decision analysis has evolved into a mature professional discipline [4] which has developed series of methods that have been and are used to support business and public-policy decision-making, often in cases where the decisions aim to resolve large, complex, and critical problems (cf. [4]).

One of the (Wikipedia) definitions states, "decision analysis (DA) is the discipline comprising the philosophy, methodology, and professional practice necessary to address important decisions in a formal manner". Then why do we not come across DA to guide the composition and selection of HEPA programs? The guide to best decisions with DA models (Wikipedia) handle "uncertainties through subjective probabilities for which the decision maker's attitude to risk is represented by utility functions and the attitude to trade-offs between conflicting aspirations (e.g. re composition of HEPA programs) are expressed with multi-attribute value or multi-attribute utility functions; utility functions can be replaced by the probability of achieving a wanted aspiration level. There is some doubt if this guide to best decisions, despite being theoretically and logically precise, is very useful for our context.

The principles of decision analysis have been reinterpreted, enhanced, and adjusted over the years to meet the needs from growing complexities of large, multinational, dynamically interdependent industries, and corporations that in ever growing competition adapt to dynamically evolving innovations. The reinterpretations introduced methods and algorithms that are mathematically more advanced and more powerful to meet the challenges from complex problems formed by large groups of dynamic, interactive elements, i.e. when we cannot grasp and tackle the interactions. The reinterpretations formed the theory and methodology of operational research, management science, multiple criteria decision making, etc. that have offered formal frameworks for important decisions from 1980'es through 2020'es. The DA theoreticians are, however, not overwhelmed by the thousands of success stories (Wikipedia) … "while there may occasionally be justification for such methods in applications (e.g., based on ease of use), decision analysts would argue for multi-attribute utility theory as the gold standard to which other methods should be compared, based on its rigorous axiomatic basis".

In the 2020'es this conceptual animosity is more or less forgotten as it has been overshadowed by the challenges of big data, which refers to problem-solving that is complicated with huge amounts of structured, semi-structured or unstructured data made available from hundreds and thousands of data sources with the help of modern, advanced ICT technology which operates 24/7 to offer instant and constant access to data sources. The decision analysis evolved into a 2020'es version called decision analytics, which now has developed the methodology and tools to work in and deal with big data environments.

Before we get into decision analytics there are a few lessons learned in the decision support systems (DSS) movement (about 1980-2010) that we could make use of for developing optimal HEPA programs for young elderly and seniors. DSS builders focused on the users' priorities, they developed systems linked to key business activities and they viewed the quality of a system from the value it gives to the users rather than the level of technology applied. DSS reflected demand economics: service, fast delivery, ease of use, benefit focused more than cost, imprecision allowed for timely delivery and user control (cf. [4]).

Analytics represents a shift in focus from both DA and DSS towards developing and delivering critical data, information and knowledge for management, decision-making, negotiations, planning, operations, (public, private sector) administration, etc. Analytics builds on theory and advanced algorithms as part of information systems, to which digital technology now is making inroads. Research used for decision analytics (cf. [5]) shows themes like big data, machine learning, business and service analytics, gamification, virtual and augmented reality, visual decision analytics, soft computing, logistics and supply chain management, explainable AI, etc. which are described as "hot topics" and which we could/should make use of for our present purposes (cf. Decision Analytics Track, HICSS).

Decision analytics, in practical terms (cf. [7]), uses combinations of mathematics and statistics, data techniques and advanced algorithms to predict and quantify performance, risk, cost, and revenue with rich data visualization to communicate valuable insights to key stakeholders and decision makers. This agenda is quite the same as for decision analysis but new technology and advances in algorithms have given decision analytics significant impact on real world problem-solving, planning and decision making.

Analytics has gained in importance in business and industry over the last 10-12 years (cf. [6-9]), but the introduction of analytic theory and increasingly advanced algorithms also meets with resistance; senior managers and executives are not comfortable with elements of black boxes (i.e., advanced mathematics) as key parts of planning, problem solving and decision making. Russell Ackoff, one of the pioneers of Operations Research [1], found (already in 1974) that mathematical models tackle and solve mainly limited and abstract representations of actual problems and that these are mostly rather useless for handling real world issues. Lotfi Zadeh (in an HICSS keynote address) had a similar message and formulated it as "you can increase precision if you are willing to give up on relevance or you can increase relevance if you are willing to give up on precision, but you cannot do both at the same time". In the 2020's we tend to forget this lesson as we aim at getting more advanced (e.g., deep and machine learning) algorithms to deal with still larger and more complex problems for which planning, problem solving and decision making need to be fast moving, highly dynamic and mostly right (not optimal).

Our quest is to find "some better ways to design, introduce and sustain HEPA programs for young elderly" than the traditional ad hoc projects and campaigns that seem not to produce any long-term, and not any sustainable, significant, and/or positive results. Our proposition is to build on systematic thinking and rational decision-making, the theory, and axioms of decision analytics, for the design and introduction of HEPA programs for young elderly. We collected more and new principles for decision support systems, decision technology, and algorithms in analytics to meet the challenges of big data, and then collected and formalized in decision analytics. The state-of-the-art methods and technology promise to support HEPA program designs that quickly adapt to changes and support choices and decisions that are mostly right (i.e., not exactly optimal but "0.95 good enough").

## 2 Decision Analytics for HEPA Programs – First Explorations

The DigitalWells program run 2019-22 and collected over 294 000 PA entries in its database from more than 1000 participants in 24+ months. It is a first implementation of decision analytics – "combinations of statistics, data techniques and algorithms to quantify performance, with rich data visualization to communicate valuable insights to DW participants (decision makers)". This was combined with cross-sectional and longitudinal studies with several samples of 100-250 participants at 4–6-month intervals to show, (i) the acceptance and adoption of the DW 3.0 application, (ii) the support of HEPA programs, and (iii) the sustainability of accepted HEPA programs. The DW 3.0 app for smart mobile phones (Android, iOS) went through several iterations with groups of users to improve its design and functionality. DW 3.0 composes and runs weekly PA programs and registers the actual activities (cf. fig.1).

The logging of activities on the smart phone is done in the left part of the screen (cf. fig.1): (i) the user selects the activity (gym training), (ii) the intensity (moderate), (iii) the date from the calendar, (iv) the duration (hours, minutes) after which the app (v) calculates and shows the effect of the PA exercise (MET-min, kcal). A MET-minute is the amount of energy spent during a minute while at rest; CPA (cf. [2]) has calibrated more than 800 PA exercises in terms of MET (metabolic equivalent of task) to show the energy spent per time unit. The MET-min measure in DW 3.0 uses the CPA calibration to give a facts-based, standardized estimate of the physical activity level of the exercise.

The most recent entries are collected in the second column and produce reports on a user's smart phone (the fourth column): (i) a specified PA report (weekly), (ii) the reported week, (iii) the PA as MET-minutes per week, and (iv) MET-minutes per day; graphical reports on MET-minutes per day, MET-minutes per activity and Minutes per activity are shown in the third column. The PA entry results update a secure, cloud-based database where the entries are stored with individual 8-digit pseudonyms for the users. The MET-min calculation is done with algorithms to decide the activity level of PA exercises (efforts and effects are functions of the user's age, BMI and gender, and the type of a PA activity). This now offers (at least) partial answers to the complaint - "you cannot be sure that the time spent will actually give sufficient health effects".

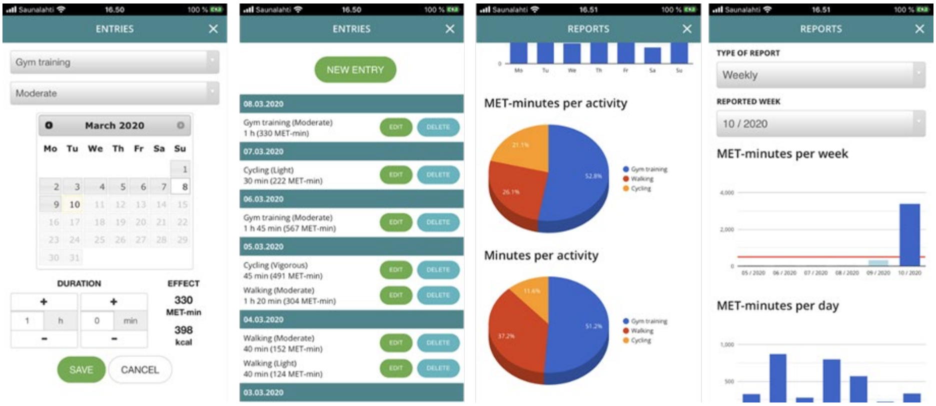


**Figure 1: DW 3.0 – A first decision analytics application**
Source: Own

The DW 3.0 uses the Wellmo platform, which offers updated interface solutions to most smart watches, and we used this feature to integrate DW 3.0 with Polar smart watches; users started to enter PA activities from smart watches, which measure heart rate and show a factual measure of the physical activity level (better than an assessment of "how demanding (1, 2, or 3) was the PA?"). With a smart watch it is also possible to measure and record several PA modules during one HEPA session. Wellmo is a multi-purpose, container platform that offers a wide range of functionalities that can be added to further versions of the DW 3.0 app. Users suggested that we include active support ("coaching") to guide them to select effective HEPA exercises and advise them on how to make progress towards better health. In some research papers (cf. [5-9]) we have worked out how digital coaching [7] could be designed and implemented for use.

## 3 HEPA Programs – User Reactions and Comments

In the DigitalWells program, Makkonen et al. [20] collected a sample of 115 young elderly who used a DW 3.0 PA logger to log, keep track of and get updates on their weekly PA exercises; daily activity data was analyzed with partial least square structural equation modelling (PLS-SEM) using the enhanced unified theory of acceptance and use of technology (UTAUT2) as the research model (cf. [28]): performance expectancy, hedonic motivation, and habit had positive and statistically significant effects on behavioural intention to adopt and use the PA logger, which is seen as a first step to adopt HEPA routines.

In two further, similar studies with different samples of young elderly participants [21], the focus was on how the adoption and use of the PA logger evolves after an initial acceptance. A longitudinal study captures "lapses" in the intention to use (and the use) for reasons which change and/or evolve over time. PA data was collected in three subsequent surveys, after four months (T1), 12 months (T2) and 18 months (T3) of using the DW 3.0 PA logger. With the UTAUT2 (cf. [28]) hedonic motivation and habit, had positive and statistically significant effects on the adoption and use of the logger; performance expectancy had a positive and statistically significant effect at T1 and T3, but not at T2; effort expectancy had a positive and statistically significant effect at T2, but not at T1 and T3. The results are interesting: (i) the construct scores stabilized over time, and (ii) declined quite strongly between T1 and T2, but less so between T2 and T3. A likely explanation is the novelty effect of the PA logger, as the scores for habit also declined strongly between T2 and T3; the effects of performance and effort expectancy appear to switch places, which could explain lapses in the use of the PA logger.

It appears that the UTAUT2 constructs primarily explain intention to use a PA logger but not necessarily the adoption and use of HEPA programs. It can of course be argued that once a PA logger is adopted with an intention to use it, the user has started PA exercises and a HEPA program.

Self-efficacy offers a conceptual framework for work on sustainable HEPA programs. Bandura [3] shows that self-efficacy beliefs affect the quality of human functioning through cognitive, motivational, affective, and decisional processes. Self-efficacy beliefs influence outcome expectations, and causal attributions for successes and failures. This quite well fits an intuitive understanding of what it would take to adapt to, adopt, and sustain HEPA programs.

In the DigitalWells Kari et al [15] studied how effective the DW 3.0 PA logger is in promoting PA self-efficacy in several groups of young elderly that had been 12 months or more with the DigitalWells program. The study traced changes in self-efficacy, at T1(+4 months), T2(+12 months) and at T3 (+18 months). A participant assesses his/her ability to exercise for 20 minutes three times per week and reports his/her personal confidence on a [0, 10] scale relative to nine statements on obstacles; an overall self-efficacy TS [0, 90] is the sum of the nine statement measures. A group of 165 participants responded to all three self-efficacy questionnaires and formed the sample. At the construct level, the total score (TS) showed a statistically significant change both at T1 and T2; the mean total score had increased from 56.0 (T1) to 62.0 (T2) and 61.5 (T3). The changes in self-efficacy were positive after 4 months and sustained after 12 months; the main explanation for the changes was found in improved mastery experience.

Bandura suggested that self-efficacy could be raised (or lowered) by non-performance means (cf. [3]) as control variables: (i) age group, (ii) gender, (iii) education, (iv) experience with apps, (v) BMI, and (vi) residential environment. The effects of the background factors were tested (with a multifactor variance analysis) on changes in self-efficacy and actual MET-minutes with difference variables. This appears to work as there were three statistically significant factors: education ($p = 0.009$), BMI ($p = 0.018$) and residential environment ($p = 0.027$); the increase between T1 and T2 is larger among university educated than for those with vocational education; the increase is smaller in the obese group than normal weight and overweight groups; the increase is larger in the big city group than in small or medium-sized city and countryside groups (cf. [15], [17], [26]).

The increase in self-efficacy for PA exercise and HEPA programs is important for sustained HEPA (e.g., [21], [26-27]). Sustained improvement in self-efficacy supports sustained adoption of HEPA programs, which contributes to health benefits as sustained improvement secures long-term health effects. Self-efficacy will not increase indefinitely, mastering PA tasks and the PA application is typically accomplished in 1-2 months, after which the novelty wears off (and no further self-efficacy increase is expected).

The self-efficacy conceptual framework, and the statistical models which are part of the decision analytics framework, points to possibilities for sustained HEPA programs. Regular health-enhancing physical activity can serve as preventive health care, which will improve and sustain quality of life and save health-care costs for an ageing population. Decision analytics models and tools gain support as they produce useful and important results.

## 4 Decision Analytics for HEPA Programs – Digital Ecosystems and Smart Systems

Digital ecosystems are part of a wave of new theoretical constructs that form the era of the digital economy; typical digital ecosystems are Airbnb and Uber, also Amazon was originally a digital ecosystem but evolved into a multi-channel platform for goods and services. The term "digital ecosystem" is used in an inflationary manner without precise definitions and in literature it appears that many terms and concepts are digital ecosystems – platform ecosystems, business ecosystems, software ecosystems, platform economy, sharing economy, etc. – without pointing to specific constructs and features. Koch et al [19] worked out a set of seven key properties that we will use to outline a digital ecosystem; five of these are relevant for our present study (DE represents Koch's "digital ecosystem-like" construct).

**KP1–service focus**. DEs establish business models in which the main revenue stream comes from the provision of combinations of digital services; services are "woven into software-based network fabrics".

**KP2–network effects**. The success of DEs is largely driven by network effects that describe the increase in value generated by an increasing user base; network effects are the primary drivers to "create and capture value".

**KP3-–shift of value creation**. DEs may generate value by connecting consumers and providers using a shared platform; such value creation is further enhanced as the number of users increases.

**KP5–openness**. Openness is understood as facilitating the system's accessibility in order to enable the "use, development, and commercialization of a technology".

**KP6–collaboration**. Collaboration may span industries, companies, or organizations. Competition, collaboration, or a mixed model of both increase productivity in DEs.

Experience gained from work with the DigitalWells program suggests that we need an extended and enhanced digital ecosystem to accommodate (i) much larger groups of users [KP2, KP3], (ii) enhanced PA Logger versions with statistics and graphics [KP5, KP6], (iii) support for service asset providers [KP1, KP2], (iv) support for service asset brokers [KP1, KP2], (v) analytics tools [KP5], (vi) knowledge base support [KP5, KP6], (vii) digital coaching support [KP3], and (viii) digital personal trainer services [KP3]. The digital platform should also include tools for local and global ad hoc group support [KP2, KP5, KP6], and support tools for easy integration with public preventive health care programs. The key properties for a digital ecosystem that Koch et al [19] worked out are shown tentatively and should be tested and validated with actual constructs. Service asset providers could participate in HEPA programs as partners and subcontractors; service asset brokers could be implemented as intelligent agent services on the platform (cf. [23-24]).

The digital ecosystem is a new and enhanced context that will allow the use of different modelling tools, more advanced algorithmic tools and software-based networking and interfacing instruments (for integrating data, information, and knowledge from a diversity of sources). This offers opportunities to develop new, enhanced versions of decision analytics that will further remove it from the restrictions of decision analysis and its guide to best decisions with DA models that handle "uncertainties with multi-attribute value or multi-attribute utility functions". In the digital ecosystem context "best decisions" are formed by service focus [KP1], shifts in value creation [KP3] and collaboration [KP6], all enabled with smart systems and intelligent technology. A first draft of such a digital ecosystem, with some interpretations of KP1-KP6, is worked out in fig. 2.

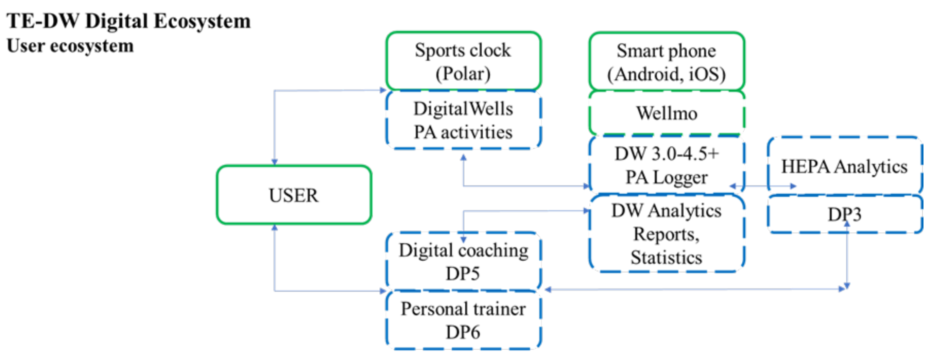


Fig.2 is the DigitalWells user ecosystem as it takes form with the sports clock and smart phone platforms. The user works with DP1, the DW PA Logger registers the activities on DP3, and the user will (later on) get support from DP5 and DP6.

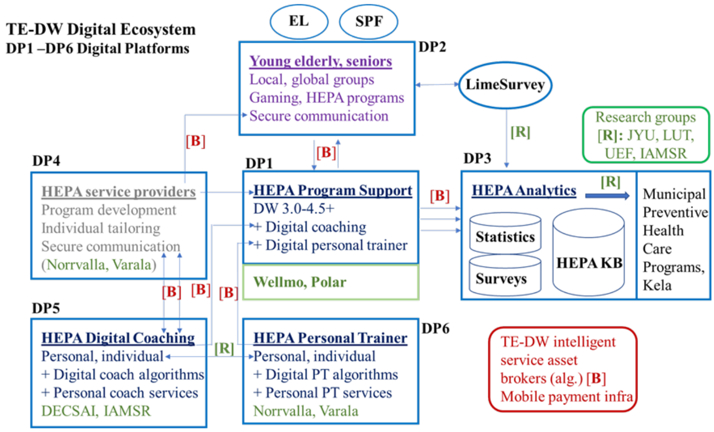


**Figure 2: TE-DW Digital Ecosystem**

Source: Own

The digital ecosystem builds on and supports six digital platforms - DP1 offers the HEPA program support with existing and new versions of the DW 3.0 PA Logger application; DP1 builds on the Wellmo platform. DP2 supports young elderly and senior HEPA program users with team and group support, inter- and intra-group collaboration, gaming and small-scale competition, secure communication, etc. DP3 supports analytics models and tools that work on HEPA program outcomes, survey statistics and a HEPA knowledge base to be used for and support preventive health care programs. DP4 invites, activates, and supports HEPA service asset providers; the first invitees are sports institutes. DP5 is an open research and development platform for digital coaching. DP6 offers a research and development platform for digital support (e.g., digital personal trainers, and nutrition counselling); both DP5 and DP6 can support HEPA specialists. The service asset broker [B] can be a partner company or can be an intelligent agent-type system that (i) onboards HEPA program service assets with program users, (ii) records and (iii) charges for the use and monitors the payment routines. The [R] represents research groups with access to the platforms to carry out research work programs. The digital ecosystem includes an infrastructure for mobile and web-based payments of digital HEPA programs.

Digital coaching is part of the digital ecosystem and is an interpretation of KP3, shift of value creation through guidance of the user. Work with digital coaching got started a few years ago (cf. [6-7]) to help human operators to master advanced automated systems in complex, very large industrial process systems. Digital coaching works with data from digital devices, instruments, tools, monitoring systems, sensor systems, software systems, data and knowledge bases, big data sets, etc. Digital coaching requires transitions from data to information, and then on to knowledge (and vice versa), referred to as digital fusion (cf. [7-9], [22]). Data fusion harmonizes data from a variety of sources with different formats; information fusion builds syntheses of data to describe, explain and predict; knowledge fusion uses ontology to build and formalize insight from data and information fusion for computational intelligence methods, AI, machine learning, soft computing, approximate reasoning, etc. (cf. [6], [22-24]). Digital fusion appears to be a key component in models and algorithms that form modern versions of decision analytics and allows progress from e.g. multi-attribute utility functions.

## 5 Summary and Conclusions

We stated the continuously recurring problem that there is a need to raise the physical activity levels in the population as this will give significant savings in healthcare costs, both long-term and in the short term. Numerous studies have supported and validated this observation. This has motivated and initiated numerous projects and campaigns during the last 15-20 years, which – however – have not produced any long-term, sustainable, significant, and positive results.

Work with young elderly showed that PA programs offered in projects and campaigns (i) were not intensive enough, (ii) were not running for enough time, and (iii) were not regular enough to be adopted and become sustainable habits for young elderly. The conclusion was to work out “some better ways”. We introduced the concept of HEPA programs (HEPA is health enhancing physical activity) and decided that the “some better ways” are to design and introduce HEPA programs for the young elderly that get adapted to and adopted for sustained use. We chose, in this paper, to show that decision analytics could be a possible approach to the “better ways”.

The DigitalWells program is a first implementation of decision analytics – “combinations of statistics, data techniques and algorithms to quantify performance, with rich data visualization to communicate valuable insights to DW participants (decision makers)”. The MET-min calculation introduced is done with algorithms to decide the activity level of PA exercises (efforts and effects are functions of the user's age, BMI and gender, and the type of PA activity). This now offers (at least) partial answers to what young elderly could (or should) do to get potentially sufficient health effects for the time they spend on their PA exercises. One of the key reasons why PA exercise programs are discontinued is the uncertainty that they actually will give the wanted health effects.

In the next step we introduced the TE-DW digital ecosystems with six platforms to guide and support users to effective HEPA programs; the digital ecosystem is also an effective and useful context for advanced forms of digital analytics that will offer more and better forms for user guidance and support.

The proposal to introduce and make use of decision analytics is part of an on-going research program that in the next phase will expand to larger groups of users (first to 3000 and then to 10 000 users) in order to harvest larger numbers of PA events from the HEPA programs. This will, in turn, allow us to apply "big data" methods and algorithms to trace trends in PA behaviour among different groups of young elderly, to estimate "typical" choices of PA events, "typical" intensity of exercises and "typical" duration of PA events. Analytics will allow us to build HEPA standards and norms, i.e. what young elderly should choose as goals to make sure that they can resolve the initial issue - "you cannot be sure that time spent will actually give sufficient health effects".

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